EFFECTS OF DOUBLE-HULL REQUIREMENTS ON OIL SPILL PREVENTION

Interim Report

Committee on Oil Pollution Act of 1990
(Section 4115) Implementation Review

Marine Board
Commission on Engineering and Technical Systems
National Research Council

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COMMITTEE ON OIL POLLUTION ACT OF 1990 (SECTION 4115) IMPLEMENTATION REVIEW

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Preface

Following the *Exxon Valdez* accident in March 1989, which spilled more than 11 million gallons of crude oil into Alaskan waters, the Congress of the United States promulgated P.L. 101-380, the Oil Pollution Act of 1990 (OPA 90). The intent of the law was, in part, to minimize future oil spills through preventive measures such as improved tanker design and operational changes and through heightened preparedness.

The Committee on Oil Pollution Act of 1990 Implementation Review was established by the National Research Council (NRC) to review and assess the effects of Section 4115 of the act. This section requires, with some exceptions, that tankers operating in U.S. waters have double hulls. Tankers must comply within a 25-year phase-in period. The secretary of transportation will assess the effects of the double hull requirement and related provisions of the act on the marine environment and on the economic viability and operational makeup of the maritime transportation industry. The results of this assessment are to be reported by the U.S. Coast Guard to Congress with recommendations for legislative or other action.

OPA 90 provisions are just coming into force. Following the publication of a National Research Council study, *Tanker Spills: Prevention by Design* (1991), double-hull design regulations were promulgated for tank vessels operating in U.S. marine waters. International rules were also amended to require double hulls, or the equivalent, in future designs. Because of the time required to implement design provisions of OPA 90, the U.S. Coast Guard requested that the deadline for the report to Congress be extended to 1997 and formally requested the assistance of the Marine Board of the NRC. In the meantime, interim structural and operational measures for reducing outflow from single-hull ships have been issued by the International Maritime Organization (IMO, a United Nations organization), but these regulations have not yet been promulgated in the United States.

COMMITTEE COMPOSITION

The Committee on Oil Pollution Act of 1990 Implementation Review consists of 15 experts in a variety of disciplines. Their fields of expertise include tanker fleet management, tank vessel design and construction, ship operation and maintenance, shipping and petroleum economics, economic analysis of construction and operational costs, marine safety, marine environmental law and policy, natural resource damage assessment, international maritime conventions, and federal regulations related to petroleum marine transportation and operations.

SCOPE OF THE STUDY

The committee will assess the effects of the double-hull design requirements and related provisions in OPA 90 on three areas expressly referred to in Section 4115: (1) ship safety and the protection of the marine environment, (2) the economic viability of the maritime oil transportation industry, and (3) the operational makeup of the industry. The U.S. Coast Guard and the NRC have also agreed to expand the scope of the assessment to include aspects of international conventions that directly affect and interact with several tank vessel structural and operational requirements of OPA 90, Section 4115. The scope of the charge to the committee is described in greater detail below.

Ship Safety and the Protection of the Marine Environment

The committee will determine changes that have occurred or can be anticipated in oil pollution in U.S. waters and in the incidence of marine casualties.[1] The committee will assess the change in the risk of oil spills resulting from, or influenced by, early retirement of tank vessels, exemptions under OPA 90, and measures for modifying single-hull tank vessels to reduce the risk of accidental spillage (in compliance with OPA 90). The committee will consider the effect on the risk of exemptions from the requirements for double-hull tank vessels: (1) tank vessels weighing less than 5,000 gross tons, (2) tank vessels lightering in designated lightering zones, and (3) tank vessels discharging at deep-water ports.

In addition, the committee will document progress in double-hull tank vessel design, construction, maintenance, and operations and identify known safety problems that have arisen with the double-hull tank vessel design.

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[1]The definition of casualty in the context of this report refers to incidents such as groundings, collisions, allisions, or structural failure, in which the vessel is damaged. It should be noted that a casualty may or may not result in an oil spill depending on the extent and location of the damage. Also, *vessel casualty* and *vessel accident* may be used interchangeably within this report.

Economic Viability of the Maritime Oil Transportation Industry

The committee will determine the effect of the act (Section 4115) on industry as may be evidenced, for example, by shifts to other modes and means of transportation, trends in shipbuilding and chartering, and changes in charter rates. The committee will also identify the added costs of construction and maintenance of double-hull tank vessels and compare them to the costs for single-hull tank vessels.

Operational Makeup of the Maritime Oil Transportation Industry

The committee will identify the nature and extent of operational changes within the industry and the safety implications that may be related to Section 4115 of OPA 90 (e.g., changes in ownership and the hull type, age, and flag of tank vessels trading in U.S. waters).

Influence of International Conventions on Tank Vessel Design and Operations

In addition to OPA 90 (Section 4115), the United States subscribes to international maritime agreements that have the effect of law. Moreover, several of these agreements or conventions parallel the tank vessel structural and operational provisions of Section 4115 and apply to most of the world tank vessel fleet. Therefore, the committee will assess the influence of international conventions on tank vessel design and operations.

For this purpose, the committee will review and comment on evidence concerning the influence of international conventions, primarily Regulations 13F and 13G, Annex 1, of the International Convention for the Prevention of Pollution from Ships (MARPOL). These conventions require changes in hull design and ship operation to reduce the risk of oil spills from tank vessels, changes that will influence the composition and character of tanker fleets. The committee will further describe how these conventions interact with OPA 90 (Section 4115) in regard to the retirement of single-hull tank vessels. This study will include a phase-out schedule for single-hull tank vessels of more than 5,000 gross tons specified in the statute; and structural and operational spill prevention measures for existing single-hull tank vessels.

The committee will assess the implementation of tank vessel statutory provisions promulgated since the enactment of OPA 90 and the implementation likely to occur during the 1995 to 2015 phase-out period for single-hull tank vessels. The study will also focus on tank barges engaged in the ocean transport of crude petroleum.

STUDY METHODS

The committee is conducting its work in two phases. The first phase addresses the accessibility and adequacy of available information for assessing the implementation of Section 4115 of OPA 90. The second phase will focus on assessments of the data obtained during the first phase.

The first phase began with an exhaustive search in the public sector for available data on the following subjects:

- double-hull effectiveness, safety, and construction
- early retirement of single-hull vessels
- fleet composition and ownership
- international maritime actions
- lightering/deep-water ports/other exceptions
- oil spills and oil spill risk
- petroleum demand
- shipbuilding
- single-hull modifications
- tanker economics and operations
- vessel casualties

The committee identified publications and reports showing promise, and synopses were disseminated to committee members for review and initial assessment. Committee members identified gaps in the information and obtained additional materials from industry sources. The U.S. Coast Guard files developed since the initiation of OPA 90 were a significant resource.[2]

Second, the committee identified a number of areas where current information was essential and invited a number of industry experts to make presentations before the committee. Their areas of expertise included maritime oil industry economics, sale and purchase brokerage, shipbuilding trends and costs, trends in inspection practices relative to double-hull tankers, and vessel finance and insurance. A list of experts who made presentations to the committee is provided in appendix C.

Third, the committee sent questionnaires to shipyard operators, owners and operators of double-hull tankers, designers of double-hull tankers, classification societies, and seagoing tank-barge operators. The questionnaires solicited information on design trends, costs, problems with double-hull vessels, and special concerns and practices unique to double-hull design.

The committee analyzed the data in terms of adequacy and availability for further assessments. Because deficiencies in the available data will hinder assessment of the implementation of the structural aspects of OPA 90, the committee identified gaps in the data and recommended ways to fill those gaps.

The committee was divided into four task groups, each responsible for analyzing the type and depth of available data. The task groups were charged with

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[2]In addition, the committee identified a number of organizations (see appendix D) as sources of pertinent but less accessible information. Later in the study, the committee will contact these organizations to obtain specific data.

ascertaining if sufficient data were readily available and, if not, determining what could be done to fill those gaps. Finally, the groups were asked to determine if expected data would be sufficient for the committee to complete its task.

After publication of this interim report, the committee will request public comments for consideration in assessing the data acquired during the first phase of the study. Following the review of comments, the committee will determine if the quantity and quality of available data are sufficient. The scope of the second phase will then be amended as necessary. The second phase of the study will encompass data assessment, the development of findings, and the preparation of the final report. The final report may contain recommendations based specifically on the findings of the committee.

The information and data provided to the committee are working papers and are not available for public dissemination. Inquiries should be made directly to the identified information source.

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Executive Summary

One reason Congress enacted the Oil Pollution Act of 1990 (OPA 90) was to reduce the occurrence of oil spills through preventive measures and to reduce the impact of future oil spills through increased preparedness. Section 4115 of the act requires that tankers operating in U.S. waters must have double hulls. Tankers must comply with this double-hull requirement within a 25-year phase-in period. The secretary of transportation must establish regulations concerning single-hull tank vessels until they are retired. Some exceptions to the retirement schedule have been made for tank vessels that unload in offshore oil ports or use zones in the Gulf of Mexico designated for lightering (the transfer of loads to smaller vessels that can enter shallow ports).

Congress requested a report on the effects of the act on: (1) ship safety and protection of the marine environment, (2) the economic viability of the maritime transportation industry, and (3) the operational makeup of the industry. In 1994, the National Research Council (NRC) established the Committee on Oil Pollution Act of 1990 (Section 4115) Implementation Review, under the auspices of the Marine Board, to study these effects. The U.S. Coast Guard, acting on behalf of the U.S. Department of Transportation, asked the NRC to conduct a study and prepare a report for the U.S. Coast Guard to use in response to Congress. The committee determined that an assessment of the impact of double-hull requirements should also take into account the parallel hull design and ship operational requirements in the International Convention for the Prevention of Pollution from Ships (MARPOL), to which the United States adheres. In addition, the committee believes that understanding the technical changes in tank vessel design and operational experience is important in developing a complete assessment of the effects of OPA 90 (Section 4115) on the safety and protection of the marine environment.

The committee is conducting this study in two phases. This interim report, completed during the first phase, reviews the availability and adequacy of the data and information needed to assess the effects of OPA 90, as requested. In the second phase of the study, the committee will assess the data and draw conclusions, which will be summarized in a final report to be issued in early 1997.

The following are the committee's findings regarding the availability and adequacy of data.

Ship Safety and Protection of the Marine Environment. Sufficient data are available to ascertain the number and volume of oil spills prior to and after the enactment of OPA 90. However, some governments and operators have taken action to enhance ship safety and environmental protection that complicate the effort to determine the effects of Section 4115 of OPA 90. In addition, mandated changes in vessel construction and operation are only now coming into effect, and interim measures for existing single-hull tank vessels have not yet been promulgated domestically.

Economic Viability of the Industry. The data required to assess the economic effects of OPA 90 and MARPOL are readily available. Although the data should be adequate for making an assessment, comparing various data sources and determining maintenance costs could be difficult. Data are available to support committee estimates of world capacity for constructing new tankers in relation to projected demands. The committee will review these capacity data and compare recent delivery levels to the demand for new tankers.

Operational Makeup of the Industry. The data are generally adequate for assessing changes in the operational makeup of the maritime oil transportation industry. Information on larger tanker operations (ships weighing more than 30,000 deadweight tons) are particularly complete and available. One area of uncertainty is likely to be evaluating changes in and forecasts of shipping patterns, including the effects of offshore terminals and lightering.

Changes in Tank Vessel Design, Maintenance, and Ship Operations. Extensive studies and model tests to determine the effects of grounding and collisions of double-hull tankers have been underway at universities and government facilities in the United States and abroad. The committee will continue to review new double-hull designs and test results and to evaluate improvements in design, construction, and maintenance to increase ship safety and reduce oil outflow after an accident. The committee believes sufficient information will be available to assess progress in double-hull vessel design since 1990. This information, along with operational experience gained from the long service of a small number of double-hull vessels and from new double-hull tankers, will be analyzed for implications for improved safety.

1

Introduction

OIL POLLUTION ACT OF 1990

Following the grounding of the *Exxon Valdez* in March 1989 when more than 11 million gallons of crude oil spilled into Prince William Sound in Alaska, Congress moved quickly to pass the Oil Pollution Act (OPA 90) in August 1990. Two goals of OPA 90 were to reduce the occurrence of future oil spills through preventive measures, such as improved tanker design and operational changes, and to reduce the impact of future oil spills through heightened preparedness. The act calls for far-reaching efforts to reduce oil pollution by mandating major changes in the way tank vessels transport oil in U.S. waters and by specifying which vessels can carry oil. For the first time, Congress effectively recognized that although vessel casualties[1] cannot be prevented entirely, improvements in the design and operation of oil-transporting vessels can minimize the amount of oil spilled in the event of a casualty. OPA 90 addressed a number of areas of concern, including oil pollution liability and compensation, spill response planning, and international oil pollution prevention and removal.

Other preventive measures addressed are alcohol and drug abuse, licensing and registry, manning standards, vessel traffic services, the periodic gauging of the plating thickness of commercial vessels, overfill and tank monitoring devices, pilotage, and the establishment of double-hull requirements for tank vessels.

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[1]The definition of casualty in the context of this report refers to incidents such as groundings, collisions, allisions, or structural failure, in which the vessel is damaged. It should be noted that a casualty may or may not result in an oil spill, depending on the extent and the location of the damage. Also, *vessel casualty* and *vessel accident* may be used interchangeably in this report.

Because parts of the act would have a dramatic impact and could result in significant changes in the economics and structure of the industry, Congress required a review after five years of implementation of the last requirement of the act, "establishing double hull requirement for tank vessels" (Section 4115).[2] The review would assess the effects of operational and structural changes on the safety of the marine environment and on the economic viability and operational makeup of the maritime oil transportation industry. Thus, the goal of the current study is to review the preventive measures mandated by Section 4115 and to ascertain their effect on pollution prevention, safety, economics, and the composition of the marine petroleum transportation industry in U.S. waters.

Preventive measures are spelled out in Section 4115 of the act. Although these measures constitute only a portion of the OPA 90 requirements, as shown in figure 1-1, they mandate fundamental changes in the design characteristics of vessels that transport oil in U.S. waters. The act mandates the replacement of pre-OPA 90 single-hull tankers that call at U.S. ports with double-hull tankers, according to a prescribed phase-out schedule. In addition, Section 4115 requires that the U.S. Coast Guard develop regulations pertaining to structural and operational measures to reduce the outflow of oil from existing single-hull tankers until these vessels are retired. The rationale behind this mandate is the presumption that double-hull tanker designs and significant changes in the structure and operational procedures of existing single-hull tankers will reduce the risk of oil spills from tanker casualties or will minimize the amount of oil spilled from such casualties. The effect of the phase-out schedule on the world fleet of single-hull vessels is shown in figure 1-2, which indicates the number of single-hull vessels remaining at the end of each year. This estimated percentage is based on the size and the age of existing tankers and on the schedule specified in OPA 90 for phasing out single hulls of various sizes and ages.

The effect of this phaseout on oil pollution depends on the effectiveness of the double-hull design in preventing the flow of oil following a casualty. In a 1991 NRC study on double-hull tankers, a committee concluded that double-hull vessels would reduce the outflow of oil in the event of a casualty, resulting in fewer or less severe oil spills than single-hull tankers (NRC, 1991). Expected reductions in oil pollution would then follow the pattern shown in figure 1-2, and the amount of oil pollution would be reduced in proportion to the percentage of single-hull vessels retired.

In addition to the construction and operational impacts of OPA 90, the tanker industry was forced to reevaluate the manner in which it carries oil, in light of the strict liability provisions for oil spills and the increased costs of operation in case of accidental oil spills. These increased costs come at a time when both the market

[2]Although Section 4115 of the act is entitled "establishing double hull requirements for tank vessels," it also establishes requirements for developing interim measures for the single-hull fleet until all these vessels have been phased out under the mandates of the section.

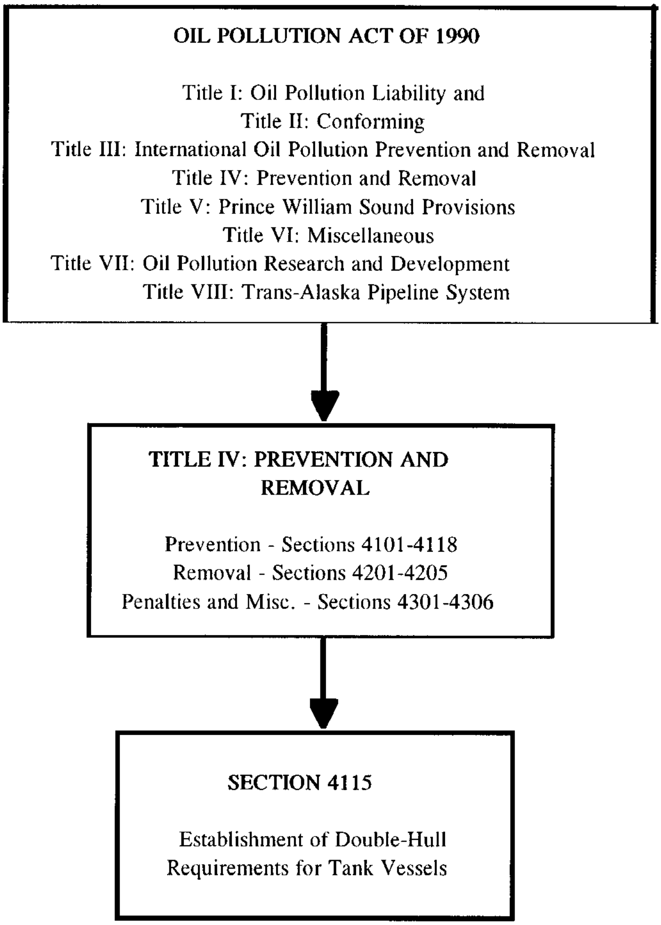

FIGURE 1-1 Relationship of Section 4115 to the Oil Pollution Act of 1990.

for tankers and oil shipping rates are emerging from a depressed period when income was often insufficient to cover the costs of operation and capital investment. Section 4115 of OPA 90 adds to the economic variables of the maritime oil transportation industry by mandating changes in the configuration of vessels the industry uses to transport oil. The costs associated with these changes will have to be borne by the industry in terms of higher expenses and, perhaps, by the public in terms of higher prices for oil products.

A number of difficulties in assessing changes in the marine petroleum transportation system have emerged as a result of OPA 90. First, the effects of Section 4115 are only beginning to be felt in the market because the first mandated

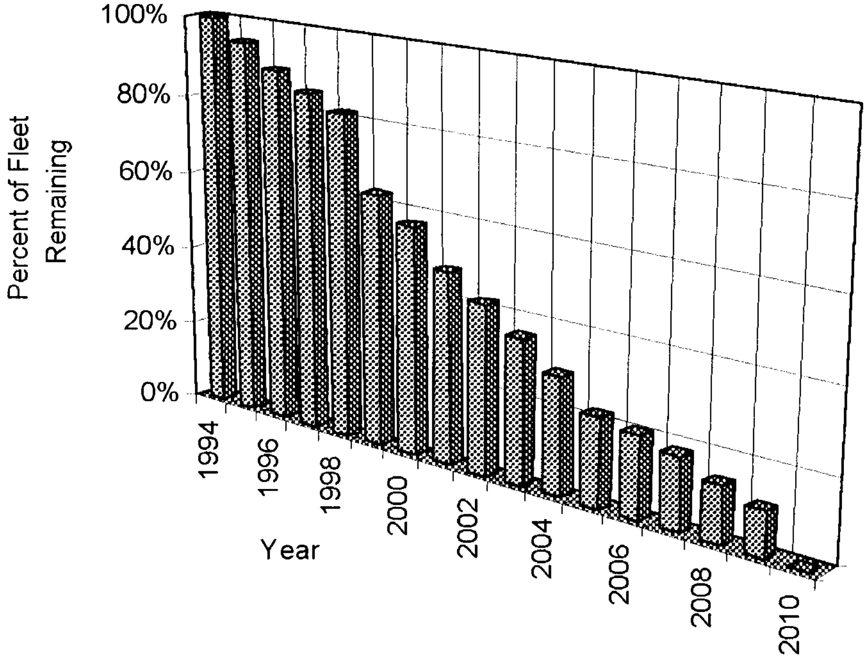

FIGURE 1-2 Percent of remaining world tanker fleet tonnage based on OPA 90 single-hull tank vessel phase-out schedule. Note: Exceptions for lightering and deepwater ports will extend the trading life of single-hull vessels to 2015. Data include accidents involving tank ships and tank barges. Compiled using data from Clarkson Research, Ltd. (1995)

retirements took place in 1995 and tankers constructed after the promulgation of OPA 90 are just entering service. Second, other parts of OPA 90, such as increased liability provisions and the potentially high cost of oil spills, have combined to force internal changes in the way vessel owners and operators run their vessels to lessen the risk of vessel casualties. Changes in the international regulatory environment, enhanced surveys, the increased vetting of vessels by charterers, and increasing port state control activities are also affecting the safety of ships carrying oil. Finally, the act may affect the number of vessels calling on U.S. ports because of new operational requirements, such as hydrostatic loading and increased under-keel clearance, as well as changes in lightering patterns resulting from double-hull exemptions. These factors affect the safety of the overall fleet, either by preventing casualties that could result in oil spills or by decreasing the number of vessels subject to casualties. Figure 1-3 depicts the interrelationships of the various factors affecting the safety of the oil transportation system. The influence of Section 4115 on safety improvement is clearly intertwined with other factors; thus, the effects are difficult to isolate. The significance of major factors is discussed below.

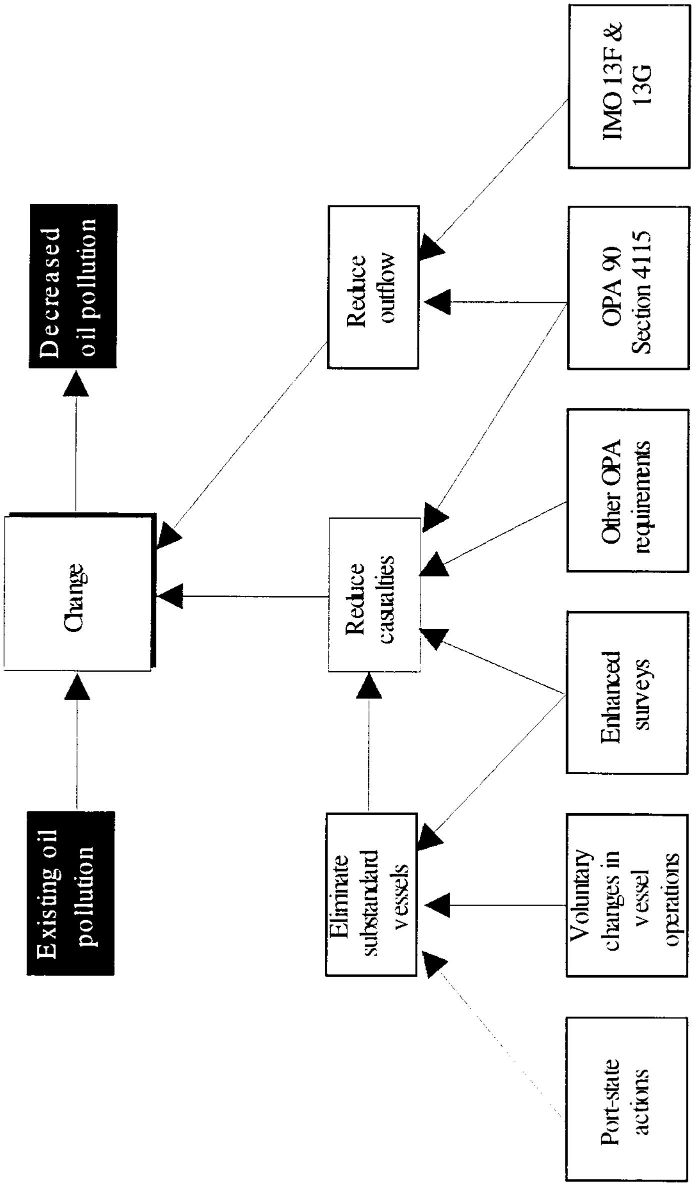

FIGURE 1-3 Post-1990 initiatives with potential impact on oil pollution from tank vessel accidents.

FACTORS AFFECTING SHIP SAFETY AND POLLUTION PREVENTION

International Regulatory Regime

The International Maritime Organization (IMO) regulates international shipping through adoption by its members of a number of conventions, including the International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978 (MARPOL 73/78) and the International Convention on Safety of Life at Sea, 1974 (SOLAS 74).

In November 1990, the United States submitted a proposal to the 30th session of the IMO Marine Environment Protection Committee (MEPC30) to establish an international requirement for double-hull tankers. This proposal eventually resulted in the adoption of Regulation 13F of Annex I of MARPOL 73/78 on March 6, 1992.

Regulation 13F specifies hull configuration requirements for new tankers contracted on or after July 6, 1993, of 600 DWT[3] capacity or more. Oil tankers between 600 DWT and 5,000 DWT must be fitted with double bottoms (or double sides), and the capacity of each cargo tank is specifically restricted. Every oil tanker of more than 5,000 DWT is required to have a double hull (double bottom and double sides) or the equivalent. These requirements are compared with those of OPA 90 in table 1-1.

The IMO regulation specifies that other designs may be accepted as alternatives to double hulls, provided they give at least the same level of protection against oil pollution in the event of collision or grounding and they are approved, in principle, by the MEPC, based on guidelines developed by the IMO. The guidelines employ a probabilistic methodology for calculating oil outflow and a “pollution prevention index” to assess the equivalency of alternative designs.

In addition, IMO Regulation 13G addresses existing single-hull vessels in the world fleet. This regulation applies to crude oil tankers of 20,000 DWT and above and oil product carriers of 30,000 DWT and above and specifies a schedule for retrofitting (with double hulls or equivalent measures) or retiring existing single-hull tank vessels 25 or 30 years after delivery. The differences between the Regulation 13G and the OPA 90 schedules are shown in table 1-2.

Pre-MARPOL tankers, which are not fitted with segregated ballast tanks (SBT) or are fitted with SBTs that are not protectively located (PL), must convert to double hulls upon reaching 25 years of age. MARPOL tankers are obligated to undergo conversion upon reaching 30 years of age. By July 6, 1995, all subject vessels must install or designate protectively located double-side (DS) or double-bottom (DB) tanks or spaces. In appropriate locations, SBTs would be acceptable as protectively located spaces.[4]

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[3]Deadweight tons (DWT) is a measure of the cargo capacity of a ship.

[4]Segregated ballast tanks (SBTs) are tanks designated for ballast only.

TABLE 1-1 Comparison of Requirements of OPA 90 and IMO Regulation 13F for New Vessels

	Size	Hull requirements	Enforcement date
OPA 90 Section 4115	<5,000 GT[a]	Double containment systems	Building contract placed after June 30, 1990 Delivered after January 1, 1994
	>5,000 GT	Double hull	Building contract placed after June 30, 1990 Delivered after January 1, 1994
IMO Regulation 13F	<600 DWT	Not applicable	
	600–5,000 DWT	Double hull or double sides	Building contract placed after July 6, 1993 New construction or major renovation begun on or after January 6, 1994 Delivered after July 6, 1996
	>5,000 DWT	Double hull or equivalent	Building contract placed after July 6, 1993 New construction or major renovation begun on or after January 6, 1994 Delivered after July 6, 1996

[a]Gross Ton (GT) is a measure of the registered tonnage and is not directly related to cargo capacity.

Regulation 13G also accepts hydrostatic loading[5] and other alternatives (operational or structural) to protectively located spaces. The United States has reserved its position on the 13G loading and structural provisions applicable to existing single-hull tank vessels and, at the writing of this report, the U.S. government had not issued regulations under OPA 90 for existing vessel structural modifications or hydrostatic balance. Regulation 13G also imposes a program of enhanced inspection during periodic, intermediate, and annual surveys for all subject vessels.

The impact of these international regulations will be analyzed by the committee in conjunction with Section 4115 of OPA 90.

[5]*Hydrostatic loading* means that the level of cargo (e.g., crude oil) is limited to assure that the hydrostatic pressure at the tank (and ship) bottom is less than the external sea pressure at that point. Thus, if the tank is breached, sea water flows in.

TABLE 1-2 Comparison of Requirements of OPA 90 and IMO Regulation 13G for Existing Vessels

	Size	Hull requirements	Enforcement date
OPA 90 Section 4115	<5,000 GT	Double containment systems	After January 1, 2015
	>5,000 GT	Double hull	Per schedule starting in 1995
	>5,000 GT	Structural operational and structural measures	No date set
IMO Regulation 13G	Crude carriers >20,000 DWT	Double hull or equivalent	If pre-MARPOL w/o SBT, 25 years after date of delivery
	Product carriers >30,000 DWT		If pre-MARPOL with SBT, 30 years after date of delivery If MARPOL, 30 years after date of delivery
		PL/DS or PL/DB or PL/SBT or hydrostatic balance loading or equivalent	As of July 6, 1995

Code: PL/DS–protectively located tanks, double side
PL/DB–protectively located tanks, double bottom
PL/SBT–protectively located tanks, segregated ballast tanks

Other Domestic and International Actions

Port state inspection programs, enhanced surveys by classification societies, and increased vetting[6] by charterers are the three major initiatives that have been undertaken since the adoption of OPA 90. Because the OPA 90 provisions concerning single-hull tank vessels under consideration in this report have not yet been implemented, and double-hull requirements have only recently been incorporated in new construction, consideration of these inspection and survey developments may elucidate the changes in spill patterns since the passage of OPA 90.

Port State Effects on Ship Safety

Port state control efforts have increased substantially in the past few years. Historically, port states (nations that have vessels calling at their ports) have not exercised substantial control over vessels that use their ports, delegating the responsibility to flag states (nations in which vessels are registered) to ensure that

[6]Vetting is the quality assessment review of the history of a particular vessel conducted by a charterer prior to entering into a chartering agreement.

vessels meet all levels of soundness. Traditionally, this role has been left to vessel owners, flag states, and ship classification societies. Because of a concern that substandard vessels are still operating and that a growing number of vessel owners are registering ships in nations that do not meet their flag-state obligations, the IMO, regional organizations, and individual nations have taken action to increase port state control.

In 1994 more than 40,000 port state control inspections were conducted in Europe, Scandinavia, Canada, Australia, South America, and the United States. Currently, three regional Memoranda of Understanding (MOU) have been signed to coordinate port state programs: the Paris MOU (1982), the Tokyo MOU (1993), and the Acuerdo de Viña del Mar (1992). (See table 1-3.)

The IMO recently adopted port state control regulations that include criteria for qualifications and a code of conduct for port state control officers.[7] Compliance with the International Safety Management Code (ISMC) and revisions to the Convention for Standards for Training, Certification, and Watchkeeping (STCW) will become additional points of review for port state control programs.

In the United States, the U.S. Coast Guard has adopted a more aggressive posture as a port state. Like Australia, which published a list of the "Ships of Shame," the United States is targeting vessels for port state surveillance and is making that information available to the public. A key feature of the regional MOUs and the U.S. and Australian programs is the sharing of information among port states.

Enhanced Ship Surveys and Increased Vetting by Charterers

Enhanced surveys of vessels have been mandated by IMO Regulation 13G. The surveys, which take place every five years, require increasingly strict inspections as vessels age. The program is intended to prevent the operation of substandard ships that could cause oil spills due to structural failure. The more prominent classification societies (members of the International Association of Classification Societies) have begun aggressive programs to ensure that vessels under their classification meet or exceed present requirements.

Major charterers have developed sophisticated vetting programs, including vessel inspections, flagging patterns, and ownership and management qualification requirements, prior to chartering vessels. An indirect result of the adoption of OPA 90 has been the increased emphasis on safety in these programs.

This report, representing the first phase of a two-phase effort to review the implementation of Section 4115 of the act, evaluates the sufficiency of available data for analyzing changes resulting or expected from implementation of OPA 90

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[7]IMO Resolution A. 787 (19), Procedures for Port State Control, adopted at the 19th session of the assembly, November 23, 1995.

TABLE 1-3 Main Features of Regional Port State Control Agreements

Agreement	Paris MOU	Acuerdo de Viña del Mar	Tokyo MOU
Authorities that adhere to the MOU	Canada, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, the United Kingdom	Argentina, Brazil, Chile, Cuba, Uruguay	Australia, Canada, China, Hong Kong, Japan, Korea, Malaysia, New Zealand, Papua New Zealand, Russian Federation, Singapore, Vanuatu
Authorities that have signed but have not yet accepted the agreement		Colombia, Ecuador, Mexico, Panama, Peru, Venezuela	Fiji, Philippines, Solomon Islands, Thailand, Vietnam
Cooperating authorities	Croatia, Japan, Russian Federation, United States		
Observer authority			United States
Target inspection rate	25% annual inspection rate per country within 3 years from effective date	15% annual inspection rate per country within 3 years from effective date	25% annual regional inspection rate by the year 2000
Governing body	Port State Control Committee	Port State Control Committee	Port State Control Committee
Secretariat	provided by the Netherlands Ministry of Transport and Public Works (Rijswijk)	provided by Prefectura Naval Argentina (Buenos Aires)	Tokyo MOU Secretariat (Tokyo)
Database center	Centre administratif des affaires maritime (CAAM) (Saint-Malo)	Centro de informacion del acuerdo latinamerico (CIALA) (Buenos Aires)	Asia-Pacific Computerized Information System (APCIS) (Ottawa)
Official language	English, French	Spanish, Portuguese	English
Signed	January 26, 1982	November 5, 1992	December 2, 1993
Effective date	July 1, 1982	November 5, 1982	April 4, 1994

(Section 4115). This report represents the judgment of the committee regarding the availability and adequacy of data for answering the following questions:

- Has Section 4115 of the act been effective in reducing the amount of oil pollution entering U.S. waters from tank vessel casualties?
- Have the provisions of Section 4115 of the act had an effect on the economic condition of the maritime oil transportation industry operating in U.S. waters and, if so, to what extent?
- Have the provisions of Section 4115 of the act changed the operational makeup of the industry transporting oil in U.S. waters (i.e., who carries oil in what kind of vessels and to which ports)?
- What changes have occurred in the design and construction of double-hull tank vessels as they become the required design, rather than the exception? What are the implications for the safety of maritime oil transportation?

The report also identifies gaps in available data and methods for closing them. In areas or cases where gaps cannot be filled, the report assesses the consequences of insufficient information on the committee's ability to review the implementation of OPA 90, Section 4115.

2

Ship Safety and Protection of the Marine Environment

One goal of OPA 90 is to reduce the amount of oil spilled in U.S. waters by instituting preventive measures and to minimize the damage from oil spills by responding effectively to spills. Section 4115 of the act focuses on preventing oil spills by mandating changes in the design and operation of vessels. The committee will assess evidence of the impact of Section 4115. The key question is whether or not the marine environment has been better protected as a result of the implementation of Section 4115.

The principal requirements of Section 4115 are (1) that single-hull tankers must be replaced by double-hull tankers according to a schedule beginning in 1995 and running through 2015 and (2) that existing single-hull tankers must undergo structural and operational modifications in order to continue operating until retirement under the prescribed schedule. These changes are intended to reduce the probability of oil spills or reduce the amount of oil spilled during an event or accident.

The probability of an oil spill event (P_e) can be expressed as the product of two probability factors.

$$P_e = P_c \times P_s$$

P_c is the probability of a casualty occurring, and P_s is the probability of a spill, in the event of a casualty. The double-hull requirement of OPA 90 addresses the second factor in the equation, the probability of a spill in the event of a casualty. The structural and operational modifications to existing single-hull vessels are also directed toward the second factor, although some elements in the proposed regulations stemming from Section 4115—such as ship bridge management, training, and maneuvering regulations—focus on the first factor, i.e., reducing the probability of a casualty.

The committee will determine if Section 4115 has had a measurable effect on the probability of oil spills. Data on vessel casualties and oil spill events, in U.S. waters and worldwide, are available from a variety of sources. The U.S. Coast Guard, the IMO, and private organizations are evaluating the effectiveness of double hulls and other structural and operational changes on implementation issues considered in assessing real and potential improvements in the protection of the marine environment.

The committee will:

- review the history and causes of oil spills
- examine the effectiveness of double-hull designs in reducing oil outflow
- identify and assess the effectiveness of structural and operational modifications to existing single-hull tankers in reducing oil outflow

Other factors that reduce the probability of casualties and spills include IMO regulations 13F and 13G, port state[1] actions, industry initiatives in vetting by charterers, and enhanced surveys. The consequences must also be evaluated by the committee because they influence the enforcement of regulations for preventing accidents and oil spills.

TRENDS IN OIL SPILLS

The committee is examining trends in oil spillage from tank vessel accidents that have occurred since 1985 in relation to tank vessel hull types and general types of casualties (e.g., collisions and groundings). Accident analyses will place particular emphasis on accidents in 1994 and 1995 to determine the extent to which measures taken since the passage of the act have reduced the incidence of oil spills in U.S. coastal waters (see the discussion under Outflow from Double-Hull Tank Vessels later in this chapter). In the past four years, there appears to have been a substantial reduction in the number and severity of serious accidents, such as collisions and groundings, which have resulted in the most significant oil spills. Figure 2-1 gives a graphic example of the data sets being evaluated by the committee.

Because relatively few double-hull tank vessels are currently in service, the apparent reduction in oil spillage from vessel accidents is probably due to factors other than hull design. Therefore, the committee will examine trends in the number of accidents, the types of casualties, and the volume of oil spilled, as well as in the types and ages of the vessels involved in recent marine casualties.

[1]The port state is the country in whose port a vessel enters, while the flag state is the country in which the vessel is registered. The port state has the right under international law to enforce a convention (such as MARPOL) to which it adheres on any ship entering its ports and to initiate proceedings in the event of a violation.

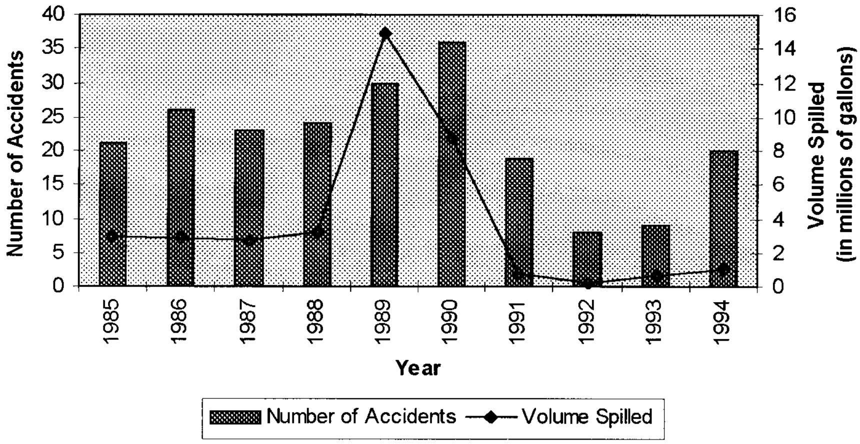

FIGURE 2-1 Oil spills from vessel accidents in U.S. waters (spills of 10,000 gallons or more). Note: Data include accidents involving both tank ships and oceangoing barges. Source: International Spill Statistics (1994).

Although it is unlikely that precise reasons can be given for the apparent reduction in oil spills, the committee will use a review of the post-OPA 90 safety record to evaluate and project the future effectiveness of the requirement for double-hull vessels.

The committee is examining oil spill statistics from the U.S. Coast Guard, the Minerals Management Service (U.S. Department of the Interior), the International Tanker Owners Pollution Federation, and two journals, *Oil Spill Intelligence Report* and *Golob's Oil Pollution Bulletin*.

Although there are inconsistencies among these sources in the level of detail and in methods of data collection, all of them report a decline in the number and severity of oil spill accidents in the past five years. During the course of this study, the committee will compile data from these five sources to ensure that all spills are accounted for and that discrepancies in the amount of oil spilled and the severity of specific incidents or casualties are reconciled. The resulting database will then be analyzed to determine if recent reductions in oil spills are indeed significant.

OIL OUTFLOW FROM DOUBLE-HULL TANKERS

After studying the design and construction of new double-hull vessels, the committee will conduct an analysis, applicable to both tank ships and oceangoing tank barges, to ascertain the impact of design on oil outflow (see chapter 5). This analysis will be applied to spills that occurred in 1994 and 1995 to estimate what might have occurred if the vessels involved in the accidents had been equipped with double hulls. If the accident involved a double-hulled vessel, the committee will analyze the amount of oil that would have been spilled if it had been a single-hull vessel.

Data for the analysis described above will be derived from a study to be conducted for the committee to determine the outflow parameters for a number of single- and double-hull tankers and barges in accordance with IMO methodology (IMO, 1994).[2] The outflow parameters will be used to compare the environmental performance of single-hull and double-hull vessels. The expected frequency of collisions and groundings will be estimated from a statistical analysis of actual casualty data in U.S. waters. The outflow functions will then be applied against the frequency of casualty data to estimate the amount of outflow if all vessels have double-hull arrangements. Additional information about the committee-sponsored study can be found in chapter 5.

MEASURES FOR REDUCING OUTFLOW FROM SINGLE-HULL TANKERS

The U.S. Coast Guard is developing regulations that comply with the OPA 90 requirements. A draft notice of proposed rules has been released and made available for public comment. The proposed changes would effectively require modifying all single-hull vessels that desire to continue trading in U.S. waters. Extensive public comments on that rule-making resulted in supplemental notices modifying the draft notice. Although the retirement schedule for single-hull tank vessels has been established by law, as provided in OPA 90 (Section 4115),[3] other U.S. Coast Guard regulations for single-hull tankers have not been completed. The U.S. Coast Guard has published a supplemental notice of proposed rules affecting the existing single-hull fleet (Federal Register, 1995). The proposed regulations address operational changes, bridge resource management training, work-time restrictions, enhanced surveys, maneuvering standards, and requirements for under-keel clearance.[4]

These regulations are intended to reduce potential casualties. Still to be developed and promulgated are regulations to reduce potential oil spillage through structural changes or vessel-loading practices. The effect of these regulations on

[2]IMO (1994) presents a probabilistic methodology for assessing the accidental oil outflow performance of alternative tanker designs. Historical tanker damage statistics are used to determine the distribution of the extent of damage from side and bottom impacts.

[3]See 33 CFR 157.10(d) for double-hull tank vessel design requirements.

[4] *Requirements for under-keel clearance* means limiting the cargo weight to ensure that the draft of the ship is reduced to allow an established minimum clearance above the sea floor or channel bottom while the vessel is underway. Under-keel clearance requirements are intended to be an accident prevention measure, while hydrostatic loading, discussed in chapter 1, is intended to reduce spillage *after* an accident.

spills and industry economics cannot be determined until they have been finalized. The effects on different fleets will vary widely, depending on the age, design, and size of the vessels.

Provided that the Coast Guard regulations for single-hull tankers are issued in time to be considered, the committee will use studies by the U.S. Coast Guard and others to evaluate the effect of regulations on reducing outflow from the single-hull fleet.

FLEET SAFETY

The quality of the fleet serving U.S. ports appears to have improved as a result of the passage of OPA 90. The committee will investigate how new international regulations, increased port state activities, enhanced surveys by classification societies, and improved vetting by major charterers and the increased fear of liability have affected the safety of the fleet serving the United States. This investigation is described below.

International Regime

Because international regulatory requirements are only now taking effect, as is the case with Section 4115 regulations, current spill rates are not expected to be directly linked to them. The international regulations can be expected to have an effect in the future, however, especially structural requirements (protectively located tanks) and operational requirements (hydrostatic balance and light loading). The structural and operational provisions for single-hull vessels apply to the world fleet. However, the United States has not yet accepted these provisions for existing tank vessels. The committee projections regarding potential oil pollution from future spills will take into account the requirements of both OPA 90 and IMO Regulations 13F and 13G.

Port Safety, Enhanced Surveys, and Improved Vetting

The three initiatives described above are intented to reduce the number of substandard vessels currently being used, at least in countries actively pursuing the initiatives. The committee will investigate the activities of major port states, classification societies, and major charterers in identifying substandard vessels (and the owners and registry of vessels). The identity of these vessels, owners, and registries will be compared to the vessels that called on U.S. ports in 1990 and 1994 to evaluate the quality of the fleet. Data on vessel port-calls have been obtained from the Institute of Shipping Analysis in Göteborg, Sweden. Data on individual fleets, owners, and registries will be developed from published information from port states and the U.S. Coast Guard and through quality grading systems such as those developed by Clarkson Research and the Tanker Advisory Center.

FINDINGS

Data are available to ascertain the number and volume of oil spills prior to and after the enactment of OPA 90. Consistency among these sources is limited, however, in terms of the range of spill volumes. Various sources define the lowest, or minimum, spill size as 500 gallons, 1,000 gallons, and 1,000 barrels.[5] There is also some inconsistency among sources as to which vessels are included and the volume of particular spills. Nevertheless, a suitable database can be developed by cross-checking and comparing information from various sources.

Endeavoring to isolate the effect of Section 4115 of the act on real or apparent changes in oil pollution rates and volumes is complicated by two factors. First, safety-related activities of the maritime oil transportation industry and regulators have increased worldwide. Second, because the required phase out of single-hull vessels only started in 1995, Section 4115 of the act has had little effect thus far on the overall incidence of oil spills in U.S. marine waters. In addition, possible structural and operational regulations applicable to single-hull tank vessels have not yet been issued. Nonetheless, the committee believes that examining the long-term trend in the occurrence, magnitude, and nature of marine oil spills may be important in forecasting the future effects of the double-hull provisions of Section 4115 as soon as they are fully implemented. The committee believes that existing data sources are adequate in this respect and that the apparent decline in structure-related casualties in the past several years can be tested for statistical significance. To the extent that statistical results will allow, a comparative oil outflow evaluation of single- versus double-hull designs will be used to determine how full implementation of Section 4115 might alter future trends in oil spillage.

[5]Volumes may be expressed in barrels. One barrel is equivalent to 42 U.S. gallons or 35 imperial gallons.

3

Economic Viability of the Maritime Oil Transportation Industry

To assess the effects of OPA 90 on the economic viability of the maritime oil transportation industry, the committee will examine how the industry—including both tankers and oceangoing tank barges—is changing under the impetus of the new legislative framework. Specifically, important changes in the size and shape of the fleet from 1990 to 1994 must be traced, and the likely changes from 1994 to 2005 and beyond must be projected.

From a regulatory perspective, two key economic questions must be addressed.

- Will there be a sufficient supply of tankers and oceangoing barges to meet U.S. oil transportation needs throughout the transition from single- to double-hull tank vessels?
- What is the expected effect on transportation costs of the change from single- to double-hull tank vessels?

The discussion in this chapter focuses on acquiring the data and information needed to answer these two questions.

Economic data on the tanker industry are widely available from several sources. However, the numerous sources of data on most topics are rarely in exact agreement. Using the best available data, the committee will undertake the following tasks:

- determine historical tank vessel demand and forecast future demand
- determine historical tank vessel supply and forecast future supply
- compare the projected supply and demand with shipbuilding capacity
- develop cost data for single- and double-hull tank vessels

- determine capital and the cost of capital required for new shipbuilding
- integrate the above elements into a required freight-rate analysis for future fleets
- calculate required freight rates (the rate shipowners must receive to cover operating and capital costs and to realize normal profits)

FORECASTS OF TANKER FLEET

Historical and Projected Tanker Demand

Data for the seaborne movement of crude oil and oil products will be presented in millions of barrels and millions of tons per day (MB/D and MT/D) and in millions of tons per year (MT/Y) (standard units of measurement in the trade) by geographical origin and destination for the years 1990 to 2005 for each of the principal trades. These data, furnished by the PIRA Energy Group, show interregional worldwide seaborne oil movements and intraregional U.S. oil movements. These data will be cross-checked against data from other sources, supplemented by data on non-U.S. intraregional oil movements.

The volume of seaborne oil trade will then be converted into required tanker tonnage in DWT per year by route.[1] This schedule will represent the demand for tanker tonnage, which will be computed by size (10 to 150 kDWT and over 150kDWT) from 1995 through 2005, which the committee believes will be the critical demand period.

Historical tanker fleet data are available from several sources, including Clarkson Research, Drewry, Maritime Strategies International (MSI), and Lloyd's Maritime Information Service. Data on the size and characteristics of the existing tanker fleet will be classified according to vessel type, name, flag (if U.S., whether eligible under the Jones Act),[2] year of construction, DWT, hull type (OPA 90 double hull, double side, double bottom, or single hull pre-MARPOL and MARPOL), and cargo capability (clean or dirty).

Vessel information should be computerized to facilitate further analysis. Because the Clarkson Research Tanker Register is available in electronic form, it will be used as a primary source.

Current Tanker Order Book

Tankers on order with shipyards will be identified and added to the tanker database. Information by vessel will include the characteristics identified above

[1]A ton, in this context, is a long ton, which is equal to 2,240 lbs. The long ton is nearly equal to a metric ton (often spelled *tonne*), which is 2,205 lbs.

[2]The Merchant Marine Act of 1920 (41 Stat. 988, chapter 250 of Statutes at Large) contains a provision, known as the Jones Act, that requires all domestic waterborne trade to be carried on U.S.-flag vessels. Therefore, crude oil to be transported from Valdez, Alaska, to ports in the contiguous United States must use U.S.-flag vessels.

as well as the delivery date for each vessel. The order book will be developed based on Fairplay and Clarkson's extensive databases of vessels on order.

The projected tanker supply will be based primarily on the mandatory phase-out schedule of OPA 90 and MARPOL. Using the tanker fleet data collected previously, this analysis will produce a profile of the tanker fleet by segment and year through 2015, reflecting tanker retirement mandated by OPA 90 and MARPOL. The tanker age profile, together with information on the hull of each vessel and the mandatory phase-out dates included in OPA 90 and MARPOL, should be sufficient to determine the phase-out profile for the current tanker fleet and noncomplying new construction.

Tanker Supply, Demand, and Shipbuilding

The supply and demand schedules developed by the committee will be matched, a capacity utilization rate will be derived, and an *equilibrium range* of capacity utilization will be estimated. Frequent changes in oil trade forecasts make it difficult to develop an estimate of demand. With the help of the order book data, however, it will be possible to project firm estimates of capacity utilization rates through 1997 and perhaps 1998. Thereafter, the difference between the schedules of projected required tonnage and projected available tonnage (after mandated phase outs) will be used to estimate the volume of new double-hull tanker construction and the reconstruction of single-hull units necessary to balance supply and demand. A recent study (Wilson and Gillette, 1994) provides information on current and prospective supply and demand balance for U.S. tankers and barges in the oil products trades.

This supply and demand equilibrium analysis will be supported by historical data on freight rates and vessel earnings. Although the committee does not intend to forecast market-driven freight rates,[3] it is generally assumed that, under competition, any existing or perceived shortage of tankers would cause freight rates to rise to a level sufficient to encourage new tanker construction. (Drewry and MSI estimates of projected freight rates could be of assistance in these analyses.)

Scrapping

OPA 90 and MARPOL mandate the retirement of tankers at a specified age. Vessels may be converted to double-hull configuration, scrapped because they do not meet OPA 90 or MARPOL requirements, or scrapped for other reasons. Vessels converted to double hull or scrapped because of OPA 90 or MARPOL incur an economic cost.

The economic impact analysis must include an estimate of the number of tankers scrapped for reasons other than mandated retirements. A review of the

[3]The *forecast* freight rate is an estimate of a future market rate, which, in a competitive market, is a function of supply and demand for tanker tonnage.

correlation between maintenance cost and age, the impact of special survey requirements, and the forecast rates of capacity utilization may provide some guidance. Calculating the economic cost of scrapping due to OPA 90 or MARPOL involves estimating the lost market value of tankers that might have continued in service if OPA 90 or MARPOL had not mandated their retirement. Calculating this cost is extremely complex and would be only marginally useful for this study. Instead, the regulatory impact analyses conducted by the U.S. Coast Guard will be used as input.

NEW-BUILDING REQUIREMENTS AND MARKET CAPABILITY

New-Building Requirements and Shipbuilding Capacity

As tankers are phased out under the OPA 90 and MARPOL regimes, it is generally expected that the demand for newly constructed and reconstructed double-hull tankers will rise appreciably. The assessment of the committee, as outlined above, will estimate the volume of this demand. A related analysis will determine if shipbuilding capacity will be sufficient to deliver the required tanker tonnage in the peak demand years.

As the projected demand for new tanker construction is expected to rise and peak in the next few years, the shipbuilding capacity will also increase substantially. These increases will be mostly in South Korea, which already has an impressive record in the construction of new tankers of all sizes.

In this analysis, estimates of new construction capacity will be calculated by identifying shipbuilding capacity by country, including current, historical, and projected capacities. Representatives of leading shipbuilding organizations in Japan, South Korea, and the United States have made presentations to the committee on this subject. Reports from the Shipbuilders Association of Japan, Japan Maritime Research Institute (JAMRI), and other materials are also available for committee use.

Any analysis of new tanker construction capability will have to take into account the effects of the demand for constructing other vessels (e.g., container ships, liquefied natural gas vessels, dry bulk carriers, etc.). The committee will employ the shipbuilding forecasts of non-tanker construction of Fairplay, Drewry, and others, as needed.

Capital Requirements for New Double-Hull Tanker Construction

The schedule of capital costs for meeting projected requirements for new and reconstructed double-hull tanker tonnage will be calculated for annual deliveries, based on current and estimated future shipbuilding prices. Data on current shipbuilding prices are available from Clarkson, Platou, and others. Data on future shipbuilding costs have been obtained from Japanese, South Korean, and other major shipbuilders. These data will be used to estimate the capital investment required for new and reconstructed double-hull ships. The general estimates of new construction schedules were given to financial experts who appeared before the committee to assist them in estimating the availability of capital to finance construction of new double-hull tankers.

COST DATA

New-Buildings and Conversions: Double-Hull versus Single-Hull

The cost of replacing single-hull tankers with double-hull units includes the cost of constructing new double-hull tankers and the cost of reconstructing older single-hull tankers to conform to OPA 90 and MARPOL requirements. Construction and reconstruction costs, as well as the difference in building costs between new single- and double-hull tankers, will be assessed through contact with shipyards, shipowners, naval architects, and ship brokers. Representatives of major international shipyards have made presentations to the committee, and shipowners and ship brokers have been surveyed.

Single-Hull Operational and Structural Modifications

The analysis of the cost of required modifications to single-hull tankers that continue trading with the United States is entirely dependent on the regulations developed by the U.S. Coast Guard. At the time this report was written, the U.S. Coast Guard had not published all the expected regulations. The committee analysis of these costs must await the issuance of these regulations.

Operating Costs Inputs

Aside from the differences in capital costs mentioned above, double-hull tankers will probably have different operating costs in several other respects. The primary method for obtaining cost information is a planned survey of vessel owners (INTERTANKO), the American Institute of Merchant Shipping (AIMS), and major oil company operators. Drewry has detailed data on operating costs for four tanker segments for the years 1986 to 2000, but these data will require a review to ascertain their usefulness to the committee. Specific cost elements and data sources are as follows.

- Hull and protection and indemnity insurance cost data will be obtained from presentations to the committee by shipowners, insurance brokers, and insurance underwriters.
- Maintenance cost data will be obtained from presentations to the committee by shipowners, ship managers, ship repair yard operators, and other

suppliers. The major effect of double hulls on maintenance costs is expected to occur later in the life of the vessel. Because double hulls are relatively new, this cost element will be difficult to quantify.

- Other operating cost data will be obtained from presentations to the committee by shipowners, ship managers, ship repair yard operators, and other suppliers.

Availability of Capital

Capital will be needed to finance the replacement of single-hull tankers by new double-hull tankers or reconstructed single-hull vessels. Capital availability will be of particular importance from 1998 to 2002, when tanker retirements reach their peak. Since the average lag between placing a firm order and accepting delivery of a newly constructed tanker is on the order of two to two-and-half years, firm capital commitments must be timed accordingly.

Information on capital availability will be obtained from members of the financial community, such as bankers, investment bankers, and other experts. The value of new tanker construction will be determined using the definitive schedule of demand, supply, and market balance.

The mandatory phase-out schedule specified in Section 4115 has caused several U.S. Jones Act vessel owners to change the estimated economic life of some vessels, resulting in accelerated depreciation and a decline in book value. This reduction in the operational potential of a ship or fleet can negatively affect the borrowing capacity of vessel owners and reduce their ability to finance the construction of new double-hull tankers. The committee will contact several U.S. flag operators and assess the effect of the phase out on their financial capacity in order to determine the significance of this issue. The required information will be obtained by interviewing selected maritime lending institutions and Maritime Administration (MARAD) officials regarding Title XI loans. The impact of this issue on vessel owners who trade internationally depends on the consistent implementation of OPA 90 and on the worldwide application of MARPOL.

REQUIRED FREIGHT RATE ANALYSIS

An important component of the analysis of future supply and demand is the estimate of future orders for tankers. Future orders are influenced by the return an owner requires or expects in order to invest in a new tanker. The required return depends on the perceived risk involved in investing in a new tanker. This analysis will attempt to determine the risk and, hence, the required return for tanker investments. The committee will analyze historical and current returns (profitability) for the tanker industry in order to understand the risk-and-return relationship in building new tankers. Liquidity models, adjusted cost of capital assessments, and other techniques will also be utilized. Current and historical tanker rates, operating costs, and capital costs are available from a variety of sources, including Drewry, MSI, Lloyd's Shipping Economist, Clarkson, and tanker company annual reports.

The development of a two-tiered market, in which higher quality tankers receive higher freight rates, has been predicted in the maritime press since the passage of OPA 90. The committee will determine if an additional premium rate exists for double-hull tankers (a subset of the higher quality tanker fleet). Information on this topic will be gathered through interviews with shipowners, charterers, and tanker brokers. The London Tanker Brokers Panel can provide an accurate assessment of spot and term charter rates for vessels with and without a U.S. trading exclusion.

JONES ACT TANKERS AND BARGES

The committee will acquire and assess key economic data that should reveal the effects of OPA 90 on tankers and oceangoing barges operating under the Jones Act. The committee will also present and estimate historical and forecasted demand, as well as vessel supply information. In addition, ship and barge costs and capital requirements for replacing single-hull vessels will be assessed. Data are available through industry sources and from presentations to the committee by industry representatives. The committee has noted that the barge industry is concerned about the impact of OPA 90 on the early retirement of single-hull oceangoing barges and on the financing of new construction. These concerns will be assessed as part of the review of the tank vessel trade under the Jones Act.

FINDINGS

An important aspect of the economic effects of OPA 90 and MARPOL on the industry derives from the resulting acceleration in tanker retirements (i.e., the difference in cost between mandated retirements of old tankers and the cost of replacing them routinely). For operators (including oceangoing barge operators) under the Jones Act, the cost of mandated retirements could be significant because some ships that would ordinarily have operated beyond the OPA 90-mandated retirement will no longer be allowed to operate. The committee will calculate the difference in cost between the retirement dates and the associated replacements resulting from OPA 90 and MARPOL.

The data required are readily available from a variety of sources. Unfortunately, these sources rarely agree. For answering the two key economic questions at the beginning of this chapter, the committee found the data adequate. However, several gaps in primary data have been identified.

- Tanker hull types. The existing tanker databases may not include sufficiently detailed information to identify accurately tanker hull types

(OPA 90 double hull, double side, double bottom, or single hull and pre-MARPOL and MARPOL), as they relate to the mandatory retirement schedule.

- Maintenance costs. Double-hull tankers will incur the heaviest maintenance costs beginning with the third special survey. This survey is required by the U.S. Coast Guard, classification societies, or the port state for ships approximately 15 years old. Because most double-hull tankers are new, the effects of these costs will not be known for some years.
- Future shipyard capacity. Shipyard capacity expansion in Eastern Europe and Eastern Asia (e.g., China and Malaysia) is not fully known and is not well described in published reports; but this expansion may be important in meeting future needs.

The use of forecasts adds a degree of uncertainty to the committee's analysis. No single forecast is available that adequately addresses all of the factors influencing the supply and demand for tank vessels. Unfortunately, the diverse sources of data and forecasts that will be used in this study are not all developed from the same basis and will require matching to achieve the optimal output.

The gaps in data identified previously will be handled by the committee in the following manner:

- Tanker hull types. Cross-check data on hull types with brokers and owners and fill gaps through the classification societies.
- Maintenance costs. Interview tanker owners and shipyards.
- Shipyard capacity. Determine if the identified future shipyard capacity is adequate to meet the demand for double-hull tankers. It may be necessary to augment traditional trade sources of information about plans for increasing shipbuilding yard capacity by using additional sources (e.g., personal contacts in the industry), particularly in projecting Eastern European and East Asian (including Chinese) capacities.
- Reliance on forecasts. Compare the various forecasts for consistency. The latest available forecasts will be used, and the committee will also evaluate the usefulness of the forecasts.

The gaps in data do not pose a significant problem for the analysis required in phase 2 of the study. The primary concerns of the committee are about the quality and diversity of data, as opposed to availability. Gaps in the data will make reaching conclusions in phase 2 more difficult.

4

Operational Makeup of the Maritime Oil Transportation Industry

The committee has been asked to identify the nature and extent of changes (e.g., changes in tank vessel ownership and tank vessel type) in the maritime oil transportation industry and the safety implications of changes that may be related to OPA 90 (Section 4115). The committee will also:

- determine if the utilization of deep-water ports (such as the Louisiana Offshore Oil Port [LOOP]) has been affected by OPA 90 and the exemptions
- determine if vessels are being removed from service earlier than usual because of restrictions imposed by OPA 90 or IMO Rules 13F and 13G
- evaluate changes in fleet composition resulting from OPA 90 and IMO regulations

This analysis will be based on a comparison of two base years: 1990 (before the enactment of OPA 90) and 1994 (the last year for which complete data is available). Sizes of vessels will be broken down into two broad groupings for which data are available: 5,000 to 150,000 DWT and 150,000 DWT and above. To evaluate the effect of the double-hull requirement on the composition of the industry, double-hull tankers will be distinguished from nondouble-hull tankers. The latter will be broken down into pre-MARPOL and MARPOL designs. Sales of tankers will be analyzed to determine the effects of OPA 90 or IMO (e.g., if Section 4115 is the reason for sale and, specifically, if the retirement of pre-MARPOL ships has been accelerated because of OPA 90 or IMO).

Data will be obtained from the U.S. Department of Commerce, Lloyd's Register of Shipping, Drewry, Clarkson, and other chartering and sale and purchase brokers. In the case of two-tier markets, most of the information will probably be provided by narrative input from brokers and shipowners. Data on future trends in the composition of the market may come from shipbuilders, owners, and brokers, and from extrapolation; thus, they are likely to be imprecise. Even data from the past may not be helpful because of the lack of standardization in size categories and the lack of attention to varieties of hull type in the usual reference sources.

OWNERSHIP, 1990 VERSUS 1994

The purpose of this task is to determine the effect of OPA 90 on vessel ownership patterns, as analyzed according to trading patterns and the size of oil tankers calling on U.S. ports. Previous ownership patterns and the size of oil tankers calling on U.S. ports before and after OPA 90 will be determined by analyzing data from Lloyd's Maritime Information Services and the Institute of Shipping Analysis in Göteborg, Sweden. These data cover all tanker vessel shipments for vessels of more than 30,000 DWT for 1990 and 1994. The data specify vessel name, vessel owner, size, cargo loaded, cargo type, departure port, flag, and coast of call (i.e., Atlantic, Gulf, or Pacific).

Relevant aggregates of the data will be developed for analyses, such as those shown in figures 4-1 and 4-2. These figures show oil shipments, by percent of shipments and by percent of volume, to the United States by shipowner category for 1990 and 1994, respectively. In this aggregation, vessel owners are identified and classified into one of three categories: oil companies, governments (such as Saudi Arabia), or independent shipowners. Ownership is defined as a full or majority ownership stake in the vessel. Vessels on long-term bare-boat charter or lease to oil companies are classified as oil company vessels.

Data on tank vessel movements have been acquired for 1990 and 1994 according to coast of call (Atlantic, Gulf, Pacific), vessel owner category (oil company, government, or independent), vessel size, number of shipments, total tons shipped, and age of the vessel. This information, as well as data on ownership and the sale and purchase of vessels, will be compiled by the Institute of Shipping Analysis, Göteborg, Sweden; Fearnley Research, Oslo, Norway; United Tankers, Göteborg, Sweden; and Drewry Shipping Consultants, London.

USE OF LIGHTERING AND OFFSHORE PORTS, 1990 VERSUS 1994

OPA 90 allows single-hull tank vessels, which would otherwise have been phased out, to continue to off-load cargo in the United States until January 1, 2015, by utilizing offshore deep-water ports and designated offshore lightering zones.[1] These exemptions may have the overall effect of increasing the volume of oil transported through deep-water port and lightering systems.

[1]Lightering is the process of transferring cargo, such as crude oil, from one floating vessel to another. Lightering is used principally to remove cargo from larger vessels to smaller, lower draft vessels that can enter shallow ports common to the Atlantic and Gulf of Mexico coasts of the United States.

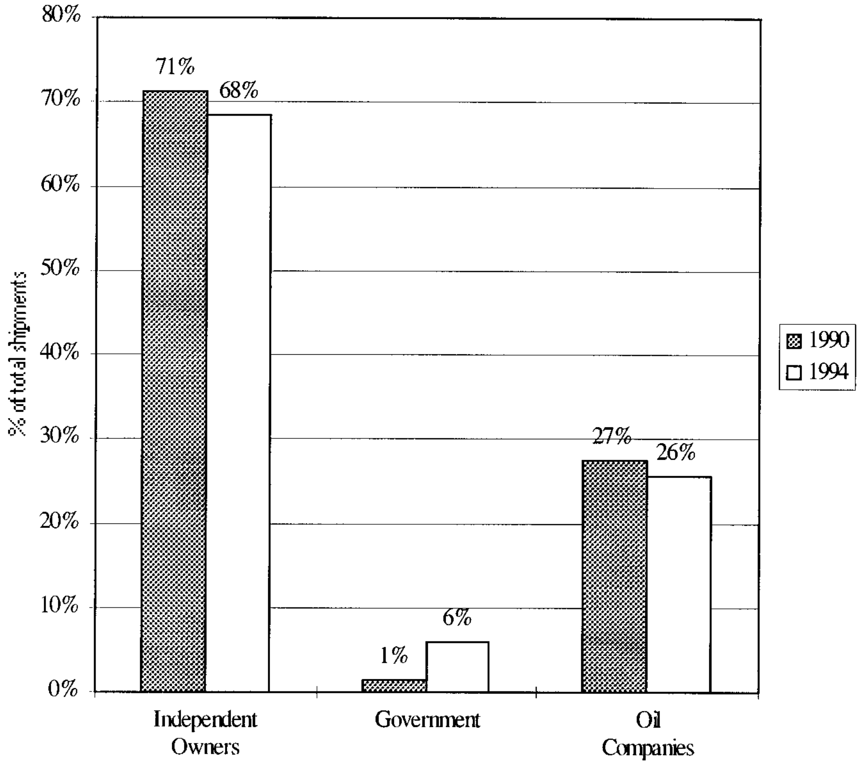

FIGURE 4-1 Change in oil shipments to the United States, 1990 and 1994. Note: Compiled using data received from the Institute of Shipping Analysis, Göteborg, Sweden (see Appendix D). Totals do not reflect 100%.

The committee will first establish historic trends in use of lightering and offshore ports for supplying U.S. refineries with crude oil. Historic data on lightering and offshore port use will be obtained from the Louisiana Offshore Oil Port (LOOP), the only existing offshore port, and published by the U.S. Department of Commerce for crude oil imports to the United States; data will be presented in the aggregate and also on a regional basis.

The historic trend will be used to project future patterns in lightering and offshore port use, from which estimates of direct, lightered, and offshore port deliveries of imported crude will be made. Where possible, regional analyses of crude oil imports will be made.

One of the uncertainties affecting changes in offshore port development and lightering patterns is the possibility of new deep-water unloading ports, such as a recently announced 2.4-million-barrel-per-day port, to be located 35 miles off the Texas coast, for unloading very large crude carriers (Oil and Gas Journal, 1995).

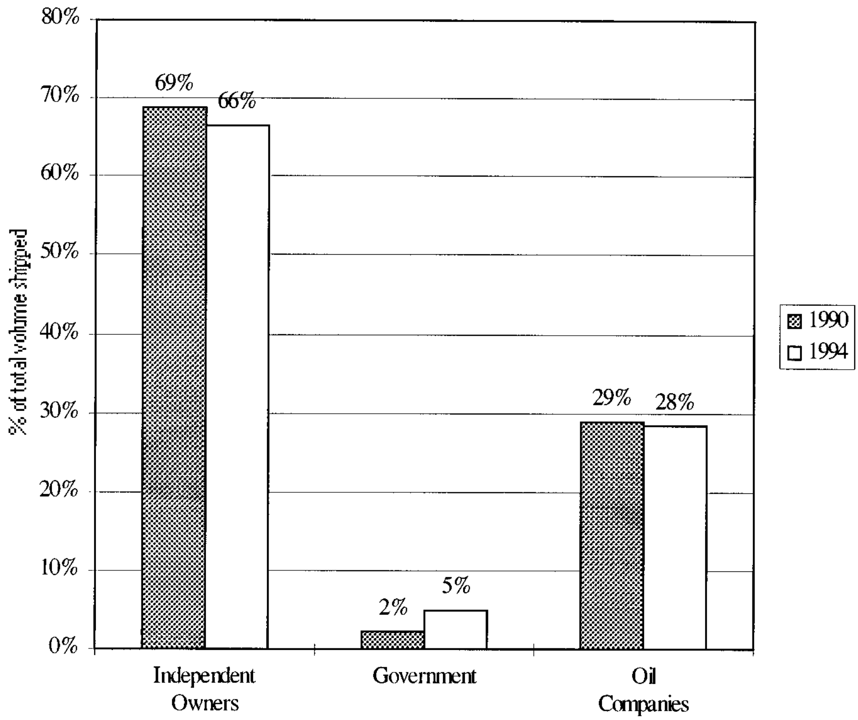

FIGURE 4-2 Change in the volume of oil shipped to the United States, 1990 and 1994. Note: Compiled using data received from the Institute of Shipping Analysis, Göteborg, Sweden (see Appendix D).

In 1994 the city of Corpus Christi began investigating an offshore terminal to serve the south Texas coast. The establishment of more ports in the Gulf of Mexico is a function of expected import volume, economics, and political pressures. Although the analysis by the committee will not address complex political variables, it will project import volume to 2010. No attempt will be made, however, to project the availability of more ports. If new deep-water ports are built in the U.S. Gulf of Mexico, the location of unloading and lightering related to those ports will be affected. The final committee report will address the general implications of changes in unloading patterns.

PATTERNS OF SALES, TRANSFERS, AND SCRAPPING

The committee will determine the impact of Section 4115 on the patterns of vessel sales, transfers, and scrappings between 1990 and 1994. The committee will also review how changes in these patterns have affected the operational makeup of the maritime oil transportation industry. In addition, the committee will attempt to predict further changes in the operational makeup of the industry that might occur because of OPA 90 (Section 4115).

The committee will collect data from various industry sources, such as Drewry and the Institute of Shipping Analysis, to establish tanker sales and ship transfers for the years 1990 through 1994. This information will be separated into categories, such as oil company, independent, and government fleets, to determine significant trends in the operational makeup of the tanker industry. Similar data may be required for the oceangoing barge industry in the United States, and, if so, these data will be obtained from the U.S. Coast Guard and verified by the American Waterway Operators. In addition, the committee will need data concerning changes in the tanker and oceangoing barge fleet operating under the Jones Act.

The data for tankers and barges will be analyzed to determine if changes are attributable to OPA 90 (Section 4115). In this area, however, the effect of OPA 90 (Section 4115) may not yet be apparent in actual sales and transfers. As additional information is obtained, the committee expects, but can not ensure, that future trends can be projected.

FINDINGS

The committee expects that available sources will be adequate, particularly for transactions involving larger vessels, the ownership of which is usually better documented than for smaller ships. Inevitably, there will be cases where the identity of buyers cannot be determined, especially in recent transactions, and this may affect the reliability of data on transfers between owners groups.

The policy adopted by some oil companies of making special arrangements with independent owners and managers to handle tankers they formerly owned introduces an element of doubt regarding ownership. This relationship cannot be assessed for at least several years. Judgments about the quality of operation are highly subjective, in any case, and none of the available criteria is entirely satisfactory.

Available data are based on different size categories, making an accurate assessment difficult. The overall figures will probably be correct, but the subdivisions may be less so. Ships often carry partial cargoes, which can effectively shift them into a different category, and crude carriers sometimes carry petroleum products (or vice versa). These variables should not invalidate conclusions, however.

Changing shipping patterns is another area of uncertainty. Whether new deep-water, offshore terminals will actually be built in the Gulf of Mexico, and, if so, when, are still unanswered questions. The use of offshore terminals and lightering zones will be governed by tanker economics. If lightering or deep-water ports are less expensive than direct shipments, their use will certainly increase as a percentage of total shipping (number of tank vessels and crude oil tonnage).

5

Data on the Design, Construction, Maintenance, and Operation of Double-Hull Vessels

One of the major concerns in congressional deliberations about OPA 90 was the ability of the maritime oil transportation industry and the shipbuilding industry to build and safely operate an economically viable double-hull fleet. Prior to OPA 90, double-hull tankers tended to be small vessels, typically product or chemical carriers rather than crude oil carriers. The imposition of the double-hull design on the entire tanker fleet by OPA 90 (at least on most of the fleet trading with the United States) has focused attention in the maritime oil transportation and shipbuilding industries on how to build safe, economical double-hull vessels.

The committee is seeking information on issues raised during discussions leading to OPA 90 on the design, construction, maintenance, and operation of double-hull tankers. This information will be reviewed, particularly in light of the operational experience of much larger double-hull vessels placed into service in the past five years. In addition, there has been considerable worldwide research in double-hull technology, primarily analytical and experimental studies on groundings and collisions. In the final report, the committee will address the implications of current research on groundings, collisions, and fatigue on current and future double-hull tank vessel designs. To address these questions effectively, the following steps will be taken:

- The present practices, concerns, and trends in the design, construction, maintenance, and operation of double-hull vessels, particularly in comparison to single-hull vessels, will be discussed and evaluated.
- Research studies and findings will be summarized, and results from the studies that influence double-hull design will be noted and discussed.
- Representative as-built, single-hull and double-hull vessels of various

sizes will be evaluated comparatively in terms of oil outflow and intact and damaged vessel stability. As discussed in chapter 2, this evaluation will be used to project the potential reduction in oil pollution from accidents.

PROBLEMS AND CONCERNS

Perceived in 1990

The problems and concerns raised in 1990 regarding double hulls primarily dealt with effectiveness of the design in preventing pollution, the increased risk of fire and explosions, possible instability of damaged vessels, perceived salvage difficulties, increased hazards to personnel in double-hull spaces, concerns about ship structural integrity and the extensive use of high-tensile steels, and concerns about corrosion in double-hull spaces.

Data pertinent to issues related to design, construction, inspection, and maintenance have been obtained from survey questionnaires sent to owners and operators of double-hull vessels, shipyards, classification societies, and naval architectural organizations. However, the data and service experience from operating double-hull vessels in the last five years may not be sufficient to determine if anticipated problems will actually materialize.

Research since 1990

Major research projects in the area of double-hull technology since 1990 have principally been carried out in the United States (by MIT, the Ship Structure Committee,[1] and the Society of Naval Architects and Marine Engineers [SNAME]), and in Japan, Denmark, and Norway. Structural research efforts in other countries have also been reported in the technical literature, such as the International Ship and Offshore Structures Congress (ISSC) proceedings. The results of these and other research will be assessed for significant effects on the design of double-hull tankers.

As an indication of the scope of research on double-hull designs, 30 papers related to the topic were presented at the International Conference on Technologies for Marine Environment Preservation (MARIENV ’95) in Tokyo, Japan (September 24 to 29, 1995), sponsored by the Society of Naval Architects of Japan. Almost two-thirds of the papers were presented by authors from Japan. The remaining papers were by authors from Denmark, Germany, South Korea, the Netherlands, Norway, and the United States. Although it is not unusual for

[1]The Interagency Ship Structure Committee is composed of the U.S. Coast Guard, the U.S. Navy Sea Systems Command and Military Sealift Command, the U.S. Maritime Administration, the American Bureau of Shipping, Transport Canada, and the Canadian Defense Research Establishment Atlantic.

most of the papers at a conference to originate in the host country, the number of reports presented at this conference reflects how much research relevant to tanker design is being conducted in Japan. In 1991, Japan initiated a seven-year structural research program, under the Association for Structural Improvement of the Shipbuilding Industry (ASIS), on the prevention of oil spills from crude oil tankers.

The three major areas in structural research on tankers are collisions, groundings, and fatigue cracking.

Collisions

Since the late 1950s, when V.U. Minorsky attempted to correlate the interpenetration of colliding ships using accident data, researchers have tried to account for the structural details and approach particulars of colliding ships (Minorsky, 1959). Early predictions of penetration were based largely on relatively simple energy accounting, but the most recent methods are based on detailed analyses of plastic buckling and collapse. The evolving methods are useful for analyzing all types of ship structure, including double hulls.

Collision analysis has been greatly aided by modern nonlinear finite element methods. In the past five years, research in this area has made increasing use of these methods, and they are now being used to optimize double-hull designs with respect to the positioning of the inner and outer hull plates, the side stringers, and the transverse webs. Verification of the procedures using large-scale model tests and actual collision data, is a necessary element of the approach because of the inherent difficulty in modeling highly contorted collapse modes and the relatively crude criteria still used to model plate- and weld-fractures during crushing.

Eight of the papers presented at MARIENV '95 dealt with structural integrity in collisions. A recent paper listing some of the representative work in this area is "Collapse of a Ship's Hull Due to Grounding" by J.K. Paik and P.T. Pedersen (Paik and Pedersen, 1995). In addition, Dutch-Japanese full-scale collision tests were carried out in the Netherlands with two 1,000-ton inland waterway tankers. Four collision cases were studied for ship structural resistance and ship movement.

Groundings

Most aspects of structural failure in tanker grounding incidents can be analyzed by the same methods used to analyze ship collisions, but hull-girder failure (i.e., *breaking the back* of the tanker) and hull tearing are features common to groundings that require specialized approaches. Hull-girder failures due to grounding have been examined with the aid of more powerful numerical models within the last five years. Issues studied include whether dynamic effects contribute significantly to hull-girder collapse and the influence of friction between the hull and the seabed. The computational models are in reasonable accord with model and full-scale controlled grounding tests. Initial efforts to assess the resistance of underside hull plates to tearing by a protrusion, such as rocks jutting up from the seabed, have been undertaken by T. Wierzbicki and colleagues at MIT (Wierzbicki, 1995). This effort is couched within the framework of fracture mechanics, where the energy required per unit length in the tearing of a plate plays a central role in the analysis. The tearing energy for steel plate must be independently measured in simulated tearing tests. Then the length of the underside ruptures is estimated by accounting for the combined energy dissipated in the grounding from tearing and from plastic deformation of the hull during interaction with the protrusion.

The mechanics of combining large amounts of plastic deformation and fracture are unusually challenging. Part of the difficulty in applying of models and tests to ship hull performance is that, although tearing energy represents a relatively small proportion of the total energy dissipated in the grounding, it is critical in determining the extent of the tear. Although difficult to develop, the integration of a sound fracture approach into collision and grounding analysis would constitute a major improvement.

Experimental test programs to evaluate ship groundings include the following:

- The U.S. Navy conducted analytical studies and large-scale model tests for strandings (loadings normal to the bottom shell) and groundings (combined normal and in-plane loadings). This program consisted of preliminary designs of double-hull vessels, grounding model tests, fatigue testing, and an analysis of the producibility of double-hull structures.
- Denmark has undertaken full-scale tests to evaluate soft groundings (Paik and Pedersen, 1995).
- The Dutch and Japanese have jointly conducted one-third-scale model tests to simulate bottom-raking damage of single-hull and double-hull tankers (Vredeveldt and Wevers, 1992; Lenselink and Thung, 1992; Wevers et al., 1994; Vredeveldt and Wevers, 1995).[2]

Fatigue

Large ships of any kind must be carefully designed to reduce the incidence of fatigue cracks, which usually start at points of high stress concentration in the hull, typically at junctions where one plate is welded to another. Some issues are specific to double hulls. In particular, double-hull vessels tend to be stiffer than single-hull vessels, and this can affect both the residual stresses induced during construction and the local stresses from loads in operation. Another contributor to potential fatigue problems, which is not specific to double hulls, is the increased

[2]Full-scale tests were conducted in 1994 in the Netherlands. Although preliminary results were presented at MARIENV ’95, they had not been published at the writing of this report.

use of thinner plates of higher-strength steels.[3] If appropriate design modifications are not made, the thinner plates will be subject to higher stresses and will, therefore, be more likely to develop fatigue cracks.

Fortunately, advances in finite element stress analysis techniques have made it possible to obtain more accurate and detailed stress estimates. Analyses of this type are now carried out routinely as an integral part of the design process by shipyards producing double-hull tankers and are no longer regarded as research studies. Experimental research in this area is under way to document the development of fatigue cracks in joints of various designs, for example, large-scale tests conducted at the Krylov Shipbuilding Research Institute in Kiev, sponsored by Lloyd's Register of Shipping (Violette, 1995). As was the case in collisions and groundings, the capability of dealing with crack initiation and growth has not progressed nearly as far as the capability of dealing with stress, deformation, and buckling. Applying fracture mechanics to ship hulls appears to be a fruitful area for research.

DESIGN AND CONSTRUCTION

Present Practices, Concerns, and Trends

The present design will be summarized based on ship data received from shipowners and operators, shipyards, classification societies, and naval architects on double-hull tankers built since 1990. Design concerns about double-hull tankers were primarily based on the trend towards the greater use of higher-tensile steels and the importance of designing structural details properly to minimize the risk of fractures and the possible leakage of oil into the ballast spaces or into the sea. Concerns have also been raised about the need for classification societies to examine strength standards for design, with a view to making tanker structures more robust.

Since 1990 some classification societies have been actively examining standards for tanker structures. The American Bureau of Shipping, for example, has developed new structural criteria and a structural software system called SafeHull for tankers (and bulk carriers). SafeHull is based on a first-principles dynamic load approach in which realistic dynamic loads are considered in the criteria. These loads include wave loads, inertia loads of the ship and cargo, sloshing loads of cargo in partially filled tanks, and cyclic fatigue loads. Finite element stress analysis is also used to evaluate the reaction of the overall structure to these combined loads. SafeHull takes into account corrosion effects expected to occur

[3]High-strength hull structural steels have strength properties in excess of the ordinary-strength hull structural steels. The properties of hull structural steels are specified in classification society rules. High-strength steels are designated by their yield strength, such as 32, 36, or 40 kg/mm^2, (yield strength characterizes the stress-strain behavior of steels). The yield strength of the ordinary-strength steel is 24 kg/mm^2.

in the hull during service life, as well as the possible modes of failure resulting from yielding, buckling, and fatigue. Lloyd's Register of Shipping has also introduced its ShipRight analysis to improve the safety of new tankers. Many of the classification society rules now have fatigue criteria and fatigue assessment methods applicable to structural details to ensure fatigue strength. The International Association of Classification Societies has also been active in establishing unified requirements to improve the design and construction of double-hull tankers. The effects of these standards on double-hull design will be assessed through an analysis of replies to questionnaires from classification societies, from direct interrogation, and from information provided by classification societies and from published documents.

Producibility: Double Hull versus Single Hull

A comparative evaluation of the producibility[4] of double-hull and single-hull tankers will be carried out based on the results of the survey questionnaire sent to shipyards. Expert testimony presented before the committee by representatives of shipyards in Japan, South Korea, and the United States will provide additional information. A significant part of producibility, the importance of coatings and their application during the construction process, will be addressed in the same manner.

INSPECTION AND MAINTENANCE

When OPA 90 was passed, several concerns were raised about the difficulty of maintaining and inspecting double-hull tankers. The 1991 NRC report by the Committee on Tank Vessel Design discussed corrosion in ballast spaces, structural cracking, safe access to ballast tank spaces, and quality of inspections (NRC, 1991).

Although double-hull vessels, both tankers and other vessel types, were in service at the time, there were no large crude oil carriers in the VLCC (very large crude carrier, approximately 200,000 to 300,000 DWT) with double-hull construction. In fact, double-hull tankers have usually been chemical tankers and product carriers. Therefore, little data from past experience were available to evaluate maintenance and inspection of large, double-hull crude carriers. Today there are a number of large crude oil tankers with double hulls in the world fleet. Because these tankers have been in service for a few years, some information on their maintenance and inspection can now be gathered. In addition, the committee will seek out and review examples of experience in liquefied natural gas (LNG), liquid petroleum gas (LPG), and liquid ammonia (NH_3), as well as chemical carriers service that have application to crude oil double-hull tanker maintenance and service.

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[4]Producibility relates to the ease of fabrication.

The committee will collect and evaluate data to identify current maintenance and inspection practices for double-hull tankers; current concerns regarding maintenance and inspection; and future trends in maintenance and inspection practices and possible effects on future designs. The differences between double-hull and single-hull maintenance and inspection will be assessed. The data supporting this assessment will be based on a survey of double-hull tanker owners and operators, as well as of shipyards building double-hull tankers; expert testimony by representatives of classification societies, operators, and shipyards; current research; and relevant literature.

Questionnaires have been sent to owners and operators, shipyards, and naval architectural organizations (see Surveys to be Conducted and Evaluated later in this chapter). The questionnaires include questions on tank inspections, coatings (types, current practices, and experiences), corrosion in ballast spaces, differences in maintenance and inspection practices for single- and double-hull tankers, accessibility to spaces, and the ability to maintain gas-free spaces. Copies of the questionnaires are provided in appendix B. Representatives of Lloyd's Register of Shipping, the American Bureau of Shipping, Hitachi Zosen (a Japanese shipyard), Hyundai Heavy Industries, Ltd. (a South Korean shipyard), and Newport News Shipbuilding Company (a U.S. shipyard) have presented expert testimony to the committee.

After collecting and evaluating the data, the committee will draw conclusions about the current state of double-hull maintenance and inspection.

OPERATIONAL CONCERNS

In addition to the concerns regarding the maintenance and inspection of double-hull tankers, other operational concerns were identified in the 1991 NRC report, namely the stability of double-hull tankers, the effect of bottom and side voids in salvage, and the risk of explosions and fires.

Relying on the current experience with double-hull tankers, the committee will collect and evaluate data on current operational practices for double-hull tankers, current operational concerns, and future trends in operational practices, and possible effects of operational experience on future designs. Operational differences between double-hull and single-hull tankers will be assessed using data from a survey of owners and operators of double-hull tankers and on current research and literature.

The questionnaire mentioned above has been sent to owners and operators of double-hull tankers. In addition to maintenance and inspection, the questionnaire solicits information on operational safety (e.g., stability during loading and discharging), access to ballast spaces, the ventilation of ballast spaces, operational procedures established for double-hull tankers, experience on current double-hull designs (the use of high-tensile steel and structural performance), design recommendations, and the advantages and disadvantages of double-hull tankers.

The committee has also identified design requirements that may have conflicting effects on vessel characteristics. Satisfying all the design requirements may require operational restrictions. For example, improved intact stability characteristics could lead to reduced damage stability performance, even though all applicable regulations have been satisfied. A comparative evaluation of intact stability, damage stability, and oil outflow characteristics of alternative single- and double-hull designs will be carried out by Herbert Engineering. The evaluation procedure is described in the next section of this chapter.

After the data collection and comparative analysis have been completed, the committee will draw conclusions on the impact of the double-hull requirement on tanker operations.

COMPARATIVE EVALUATION OF ALTERNATIVE SINGLE-HULL AND DOUBLE-HULL DESIGNS

During the preliminary design process, tank arrangements and subdivisions are developed to suit owner requirements as well as classification society, flag-state, and other relevant regulations. Within the bounds of the regulations, the designer makes decisions on the location of the cargo block, the size and location of tanks, and the dimensions of the wing tanks and double bottoms. These decisions affect a wide range of factors, including cost and weight of ships, oil outflow and pollution prevention, survivability, intact stability, and longitudinal strength of the vessel. Various trade-offs are made during the design process. For instance, increasing the wing-tank width generally reduces projected oil outflow values. However, it may have a negative effect on survivability because damage to large wing tanks will result in increased heeling and sinkage. This might necessitate more extensive subdivision of the wing tanks, which increases vessel complexity and costs.

Responses to the questionnaire regarding double-hull tanker designs indicate that shipyards have taken different approaches to optimizing their tanker designs. To assess relative improvements in the various designs compared to traditional single-hull vessels, the committee will assess the oil outflow, survivability, intact stability, and strength characteristics of double-hull tankers built in the last five years. Approximately 16 double-hull designs ranging in size from 40,000 to 300,000 DWT will be evaluated, and the results will be compared to existing single-hull tanker designs of similar sizes. The results will also be used to assess the effectiveness of current regulations regarding stability, damage stability, and outflow in maintaining consistent standards for safety and environmental performance.

SURVEYS TO BE CONDUCTED AND EVALUATED

As discussed previously, questionnaires concerning experiences with double-hull vessels were sent to owners and operators of double-hull tankers, shipyards building double-hull tankers, classification societies, and marine architecture firms. The questionnaires and the list of companies to which they were sent are provided in appendix B.

Owners and Operators of Double-Hull Tankers

Twenty-five owners and operators of double-hull tankers were sent questionnaires on the operation of double-hull tankers. The purpose of the questionnaire was to gather information on current operational experiences. The main areas covered in the questionnaire are operation, inspection and maintenance, design, and fleet information.

The committee will evaluate the questionnaires and, assuming the experience base is sufficient to validate operational concerns, draw conclusions on the effects of the double-hull requirement on tanker operations, maintenance, and inspection. Responses will also be used for a comparative evaluation of alternative designs.

Shipyards and Designers Building Double-Hull Tankers, Classification Societies, and Marine Architects

A questionnaire concerning tanker design, construction and maintenance was sent to shipyards that build double-hull tankers, classification societies, and, with slight modification, to marine architects throughout the world. The areas covered by this questionnaire include ship characteristics data for double-hull tankers built or classed, percentage of high-strength steel used, and comparison of producibility of single-hull and double-hull designs of 90,000, 150,000, and 280,000 DWT sizes. Indicators of producibility may be based on differences in labor hours and cost for steel fabrication, machinery and outfitting, coatings, total construction time (from keel laying to delivery), and any other comparative data related to construction or producibility.

Questionnaire responses will be evaluated and conclusions will be derived in the following six areas: design trends, changes in use of high-strength steel, problems and solutions to producibility of double-hull versus single-hull designs, construction practices, coating concerns, and maintenance-related problems and solutions.

FINDINGS

A review of the design information from questionnaire responses and from technical documents indicates that adequate information will be available to assess most of the concerns about the progress of the double-hull design since 1990. Data reviewed to date have not revealed any new or novel design features incorporated into double-hull designs since 1990. Most new designs were developed to meet the current double-hull requirements of OPA 90 and IMO Regulation 13F and follow standard practices. However, one finding not previously identified as a potential problem in design is the sensitivity of certain double-hull tankers to instability in the intact condition, particularly if the cargo tank is very wide.[5]

Because of relatively recent deliveries of large double-hull tankers, not much operational experience is available on long-term structural and operational effects, such as fatigue performance of the structure and corrosion protection of the ballast spaces. The committee will rely on experience from double-hull chemical and product carriers, as well as from the few double-hull crude carriers built before 1990.

After an exhaustive analysis of information from the surveys and expert testimony and a thorough search of the literature in the first phase of the study, remaining gaps in information will be filled by personal contact between committee members and individuals from various organizations and companies. This will be necessary because of ongoing changes in the process of gearing up for construction to meet OPA 90 and IMO 13F requirements.

[5]Intact stability has been extensively discussed at IMO since January 1991 as a potential problem that might require additional operating restrictions.

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List of Acronyms

13F	Regulation 13F of Annex I of MARPOL 73/78
13G	Regulation 13G of Annex I of MARPOL 73/78
ABS	American Bureau of Shipping
AIMS	American Institute of Merchant Shipping
ASIS	Association for Structural Improvement of Shipbuilding Industry
DB	double-bottom
DS	double-side
DWT	deadweight tons; a measure of the carrying capacity of a vessel
IMO	International Maritime Organization; the United Nations agency reponsible for maritime safety and environmental protection of the seas
ISMC	International Safety Management Code
ISSC	International Ship and Offshore Structures Congress
JAMRI	Japan Maritime Research Institute
LNG	liquified natural gas
LOOP	Louisiana Offshore Oil Port
LPG	liquified petroleum gas

M/T	millions of tons
MARAD	Maritime Administration, Department of Transportation
MARIENV 95	International Conference on Technologies for Marine Environment Preservation, Tokyo, Japan, September 24–29, 1995
MARPOL, MARPOL 73/78	The International Convention for the Prevention of Pollution from Ships, adopted in 1973 and amended in 1978
MB/D	millions of barrels per day
MEPC	Marine Environmental Protection Committee of the International Maritime Organization
MEPC30	the 30th session of the Marine Environmental Protection Committee
MIT	Massachusetts Institute of Tecnology
MOU	Memorandum of Understanding
MSI	Maritime Strategies International, London; a firm specializing in historical marine shipping fleet and economic data
MT/Y	millions of tons per year
MT/D	millions of tons per day
NRC	National Research Council
OPA, OPA 90	Oil Pollution Act of 1990 (P.L. 101-380)
PIRA	PIRA Energy Group
PL	protectively located
SBT	segregated ballast tanks
Section 4115	Section 4115 of the Oil Pollution Act of 1990
SNAME	Society of Naval Architects and Marine Engineers
SOLAS	Safety of Life at Sea
STCW	Convention for Standards for Training, Certification and Watchkeeping
VLCC	very large crude carrier; refers to vessels of more than 175,000 DWT

APPENDICES

APPENDIX A

Biographies of Committee Members

Douglas C. Wolcott, *chair*, served as president of Chevron Shipping Company from 1984 until his retirement in 1994. During that time Chevron had the largest oil company-owned fleet in the world, consisting of 40 oceangoing tankers with a total carrying capacity of six million deadweight tons, a smaller fleet of tugboats and barges, and 50 to 60 chartered vessels. Mr. Wolcott had been with Chevron Corporation (previously Standard Oil Company of California) since 1957, holding positions in oil-producing operations, the international fleet, traffic and chartering, and operations. Mr. Wolcott serves on the boards of directors of the American Bureau of Shipping and of London and Overseas Freighters, Ltd. He was previously chairman of the Oil Companies International Marine Forum (OCIMF), the American Institute of Merchant Shipping (AIMS), the Marine Preservation Association (MPA), and deputy chairman of the United Kingdom P&I Club. He holds a B.S. degree in engineering from the University of California at Berkeley and has completed graduate work in petroleum engineering at the University of Southern California.

Peter Bontadelli, *vice chair*, is administrator of the Office of Oil Spill Prevention and Response of the California Department of Fish and Game. He has primary authority to direct prevention, removal, abatement, response, containment, and cleanup efforts related to oil spills in the marine waters of California. His previous experience at the Department of Fish and Game included service as special assistant to the director, chief deputy director, and most recently, department director, a post he held for five years. During that time he served on various distinguished environmental panels, including the Pacific Flyway Council (where he was a former president), the North American Wetlands Conservation Council, the Pacific Fishery Management Council, the Pacific States Marine Fisheries Commission, the International Association of Fish and Wildlife Agencies, and the Western Association of Fish and Wildlife Agencies. Mr. Bontadelli received his B.A. in political science from the University of California at Davis.

Lars Carlsson is president of Concordia Maritime AB, a Swedish shipping company that operates two ultralarge cargo carriers (tankers) and six very large cargo carriers (tankers), in cooperation with Stena Bulk AB. A senior executive in international shipping and trade since 1969, Mr. Carlsson is chair of the North Europe Committee of the American Bureau of Shipping, a council member of INTERTANKO, and a frequent participant in shipping conferences. He is an industry spokesperson for building and maintaining oil tankers to the highest standards and for providing these standards through voluntary quality classification. Mr. Carlsson holds a degree in business economy.

William R. Finger, president of ProxPro, Inc., has been active in evaluating the impact of various factors on present and future prospects of the energy and oil industries. Prior to joining ProxPro in 1992, he served at the Exxon Company (USA) for 22 years, where he was responsible for evaluating the energy business environment and for representing Exxon in energy matters before the U.S. Congress and government agencies. He also represented the company on industry groups, including the National Petroleum Council, the Energy Modeling Forum, the American Petroleum Institute, and the Houston Economic Development Council. Mr. Finger received his B.S. degree from Virginia Polytechnic Institute and State University and is a registered professional engineer in the state of Louisiana.

Ran Hettena is president of the Maritime Overseas Corporation, the operating agent for the Overseas Shipholding Group, Inc. (OSG), and has been active in the shipping business for 40 years. At OSG he has been director and member of the Finance and Development Committee of the company and president of OSG Bulk Ships, Inc., the subsidiary that owns the U.S. flag fleet. Mr. Hettena has served as trustee, treasurer, and chair of the Finance Committee of the Webb Institute of Naval Architecture; chair of the Tanker Subcommittee of the U.S. Department of Transportation Maritime Advisory Committee; a member of the American Bureau of Shipping Board Managers; chair of the Committee of GARD in the Norwegian Protection and Indemnity Insurance Association; and director of the American Institute of Merchant Shipping. He has a B.S. degree from Columbia University and an M.S. in economics from New York University.

John W. Hutchinson, NAS/NAE, is the Gordon McKay Professor of Applied Mechanics at Harvard University, where he has been on the faculty since 1963. He has been an editor and a member of editorial boards for the Oxford University

Press, the Defense Sciences Research Council, the Advanced Research Projects Agency (U.S. Department of Defense), and the U.S. National Committee on Theoretical and Applied Mechanics. He is a member of the American Academy of Arts and Sciences, the Danish Center for Applied Mathematics and Mechanics, the American Society for Testing and Materials (ASTM), and the American Ceramics Society. A former Guggenheim fellow, Dr. Hutchinson is a fellow of the American Society of Mechanical Engineers (ASME) and the recipient of a number of professional awards. He has a B.S. in engineering mechanics from Lehigh University, a Ph.D. in mechanical engineering from Harvard University, and honorary doctoral degrees from the Swedish Royal Institute of Technology and the Technical University of Denmark.

Sally Ann Lentz is co-executive director and general counsel of Ocean Advocates, a nonprofit environmental organization dedicated to the protection of the marine environment. She represents environmental interests in national and international forums on ocean dumping, vessel source pollution, and other marine public policy issues, and has served as advisor to U.S. delegations to the International Maritime Organization. Her previous positions have included staff attorney for Friends of the Earth and the Oceanic Society, as well as private practice. She holds a B.A. from Oberlin College, a J.D. from the University of Maryland, and has completed post-graduate study in European Community law. A member of the District of Columbia and Maryland bars, she served on the Committee on Tanker Vessel Design of the NRC Marine Board.

Donald Liu is senior vice president for technology at the American Bureau of Shipping (ABS), where he directs the international technology activities of the organization. In his 30-year career at ABS, Dr. Liu has held positions as senior vice president of the Technical Services Group, vice president of the Research and Development Division, assistant vice president, and chief research engineer. He has published and presented numerous technical papers on ships and marine and offshore structures, primarily in the areas of design, stability, environmental loading, and computer analytical methods. Dr. Liu is a graduate of the U.S. Merchant Marine Academy (B.S.), the Massachusetts Institute of Technology (B.S. and M.S. degrees in naval architecture and marine engineering), and the University of Arizona (Ph.D. in mechanical engineering).

Dimitri A. Manthos has been president since 1962 of Admanthos Shipping Agency, Inc., of Stamford, Connecticut. Admanthos Shipping, founded in 1947, presently manages four modern product carriers in the U.S. trades and has a double-hull vessel under construction. Mr. Manthos previously held senior positions with Tropic Drilling Company of Texas and other marine-oriented firms. He is director of the U.K. Mutual Steamship Insurance Association and a member of the Det Norske Veritas North America Committee and the Bahamas Maritime

Advisory Council. He was a member and director of the Society of Maritime Arbitrators, and he served on the Ocean Industry Visiting Committee of the Massachusetts Institute of Technology, of which he is a life sustaining fellow. He holds a B.S. in naval architecture and marine engineering and an M.S. in shipping and shipbuilding management, both from MIT.

Henry Marcus, professor of marine systems at the Massachusetts Institute of Technology (MIT), is chairman of the MIT Ocean Systems Management Program and the Naval Sea Systems Command (NAVSEA) Professor of Ship Acquisition. He holds a B.S. degree in naval architecture from the Webb Institute of Naval Architecture; M.S. degrees in naval architecture, shipbuilding, and shipping management from MIT; and a doctorate in business administration from Harvard University. Dr. Marcus chaired the Committee on Tank Vessel Design, which operated under the auspices of the Marine Board of the NRC and produced the 1990 report, *Tanker Spills: Prevention by Design.*

Keith Michel is president of Herbert Engineering Corporation. In his 20 years with the company, he has worked on design, specification development, and contract negotiations of container ships, bulk carriers, and tankers. Mr. Michel has served on industry advisory groups developing guidelines for alternative tanker designs, including groups advising the International Maritime Organization and the U.S. Coast Guard. His work has included development of methodology, vessel models, and oil outflow analysis. He was a project engineer for the U.S. Coast Guard report on oil outflow analysis for double hull and hybrid tanker arrangements, which was part of the U.S. Department of Transportation technical report on OPA 90 to Congress. He has also worked on the development of salvage software used by the U.S. and the Canadian Coast Guards, the U.S. Navy, the National Transportation Safety Board, the Maritime Administration, ABS, Lloyd's, and numerous oil and shipping companies. Mr. Michel holds a B.S. degree in naval architecture and marine engineering from the Webb Institute of Naval Architecture.

John H. Robinson is a consultant in marine science issues related to offshore oil development and transportation. Mr. Robinson retired from federal service after serving for 30 years in positions with NASA and NOAA. As director of the NOAA Gulf Program Office of the Office of the Chief Scientist, he directed NOAA research to assess the effects of marine oil spills and oilfield fires in the aftermath of the Persian Gulf war. Previously, as manager of the NOAA Hazardous Materials (HAZMAT) Response Division, he developed and managed the NOAA spill response and hazardous waste site research program, established regional scientific support programs in U.S. coastal areas, and served as scientific coordinator for the Ixtoc I oil drilling spill, the *Exxon Valdez,* and other oil and chemical spills. While at HAZMAT, Mr. Robinson originated a program for the computer-aided management of emergency operations. He received his B.S. in industrial engineering from Texas Technological University.

Ann Rothe is executive director of Trustees for Alaska, a nonprofit, public interest law firm representing environmental groups, Alaska native corporations, and others in the areas of natural resources and environmental protection. Prior to her current position, she was Alaska regional representative to the National Wildlife Federation and assistant to the regional vice president of the National Audubon Society. Following the *Exxon Valdez* grounding, she worked on state and federal legislation to improve oil spill prevention and response capabilities in Alaska and nationwide and was a principal organizer of the Regional Citizens Advisory Council for Prince William Sound. She has also served on the Research and Development Advisory Committee for the Marine Spill Response Corporation and the regional technical working group for outer continental shelf activities of the Minerals Management Service. Ms. Rothe has a B.S. in journalism and wildlife biology from Iowa State University.

David G. St. Amand is president and founder of Navigistics Consulting. An expert on shipping and petroleum economics, he has been a witness on shipping and petroleum economics, conducted extensive analyses of the Alaskan and foreign tanker trades, led a reengineering effort for the crude oil supply of a major oil company, and conducted studies on the regulatory and environmental effects of hydrocarbon vapor emission regulations. He was project manager for the development of vessel oil spill response plans for a number of shipowners and operators, and has worked with owners, operators, and oil-spill response contractors to ensure their compliance with OPA 90. He also serves on the Towing Safety Advisory Committee for the U.S. Coast Guard. Mr. St. Amand holds a B.S. in naval architecture and marine engineering from the Webb Institute of Naval Architecture and an M.B.A. from Dartmouth College.

Kirsi K. Tikka is assistant professor at the Webb Institute of Naval Architecture. She was previously a senior analyst for tanker planning and economics at Chevron Shipping Company, where she performed economic analyses for marine transportation projects, including new vessel building projects, vessel charter evaluations, operation cost studies, transportation studies, and voyage economics. Dr. Tikka has degrees in mechanical engineering (M.S.) from the Helsinki University of Technology and in naval architecture and offshore engineering (M.S. and Ph.D.) from the University of California at Berkeley.

APPENDIX B

Questionnaires

Questionnaire for Owners and Operators of Double-Hull Tank Vessels

I. Operation of double-hull tankers
   1. What is your experience with operational safety of double hull tankers in regard to:
      • stability during loading and discharging
      • safe access to ballast spaces
      • ventilation of ballast spaces
      • any other safety issues that need to be addressed.
   2. Are there significant differences in cargo operations between double-hull and single-hull tankers?
   3. Have you established operational procedures specifically for double-hull tankers?

II. Inspection and maintenance of double-hull tankers
   1. Please provide information on structural and tank coating inspection frequencies and practices on double-hull tankers.
   2. What is your experience with different types of coating in ballast spaces? Have you encountered significant corrosion problems? If so, please describe.
   3. What are your current practices with regard to ballast tank coatings (include type, number of coats, thicknesses)? From your experience, what is the expected life of the coatings?
   4. Do any of your maintenance and inspection practices for single-hull tankers differ from those used on double-hull tankers?

III. Design of double-hull tankers
   1. Have you had any structural problems on double-hull tankers? Please provide information on the type of problems.
   2. What is your experience with high strength steel construction?
   3. What design changes would you suggest in future double-hull tankers?

IV. Fleet information
   1. Please provide the number and size characteristics of double-hull tankers in your fleet.
   2. Please note if any of your operation experiences are specific to certain sizes of double-hull tankers.

V. General
   1. Based on your experience, what are the advantages and disadvantages of double hull tankers as compared to single-hull tankers?

Questionnaire for Shipyard Operators, Classification Societies, and Marine Architects

I. Design Characteristics
   1. See the attached ship characteristics form for double-hull tankers. Kindly complete the form for double-hull tankers that have been built, or are under construction, or on order in your yard. An example of a completed form is provided for your guidance in completing the form.
   2. Additionally, what is the percentage of high strength steel used in each design?
   3. What design changes do you foresee in future double-hull tankers?

II. Producibility
   1. In comparing the producibility of single-hull and double-hull designs of 90,000, 150,000, and 280,000 DWT sizes, please provide an estimate of the differences (in absolute terms or on a percentage basis) of labor hours or cost between single-hull and double-hull construction for:
      a. steel fabrication
      b. machinery/outfitting
      c. coatings (include type and extent)
      d. total construction time (keel laying to delivery)
      e. any other comparative data related to construction or producibility
   2. Please describe any particular problems in double-hull construction versus single-hull construction.

III. Maintenance
   1. Accessibility of spaces: what has been your experience relative to ease of access of spaces in double-hull tankers versus single- hull tankers?
   2. Ability to gas-free spaces: what has been your experience in the ability to gas-free spaces in double-hull designs for the safe entry of personnel?
   3. Maintenance related problems: please describe any maintenance-related problems experienced with double-hull tankers.

Owners and Operators of Double-Hull Vessels Who Received Questionnaires

Name	*Location*
Acomarit (UK), Ltd.	Glasgow, United Kingdom
Acomarit Service S.A.	Geneva, Switzerland
A.P. Moller Company	Copenhagen, Denmark
Bergesen D.Y. A/S	Oslo, Norway
Bona Shipping A/S	Oslo, Norway
Ceres Hellenic Shipping Enterprises, Ltd.	Piraeus, Greece
Chevron Shipping Co.	San Francisco, California
Conoco Shipping Co.	Houston, Texas
Eletson Corporation	Piraeus, Greece
Essar Shipping, Ltd.	Madras, India
Frontline AB	Stockholm, Sweden
Gotass-Larsen, Ltd.	London
Knutsen O.A.S. Shipping A.S.	Haugesund, Norway
Mitsui O.S.K. Lines	Tokyo, Japan
Mobil Shipping and Transportation Co.	Fairfax, Virginia
Mowinckels Rederi A/S	Bergen, Norway
Naess Shipping	Amsterdam, the Netherlands
Neptune Orient Lines, Ltd.	Singapore
Neste Oy	Esbo, Finland
Ocean Technologies, Ltd.	Ft. Lee, New Jersey
Teekay Shipping (Canada), Ltd.	Vancouver, Canada
Torre Britanica	Caracas, Venezuela
Tschundi & Eitzen	Lysaker, Norway
Ugland Tanker A/S	Grimstad, Norway

Shipyards and Vessel Designers Who Received Questionnaires

Name	*Location*
AESA (Puerto Real)	Cadiz, Spain
Avondale Industries	New Orleans, Louisiana
Bremer Vulkan Werft	Bremen, Germany
Chantier de l’Atlantique	Paris, France
CSBC	Taipei, Taiwan
Daewoo Heavy Industries, Ltd.	Kyungnam, South Korea
Daewoo Heavy Industries, Ltd.	Seoul, South Korea
Fincantieri	Trieste, Italy

Halla Engineering and Heavy Industries, Ltd.	Seoul, South Korea
Hanjin Heavy Industries Co., Ltd.	Pusan, South Korea
Hitachi Zosen Corporation	Osaka City, Japan
Hyundai Heavy Industries Co., Ltd.	Ulsan, Korea
Imabari Shipbuilding Co., Ltd.	Kagawa, Japan
Ishikawajima-Harima Heavy Industries, Ltd.	Tokyo, Japan
Kawasaki Heavy Industries, Ltd.	Hyogo, Japan
Kvaerner Warnow Werft	Warnermunde, Germany
Mitsubishi Heavy Industries Co., Ltd.	Yokohama, Japan
Mitsui Engineering and Shipbuilding Co., Ltd.	Chiba, Japan
Namua Shipbuilding Co., Ltd.	Imari City, Japan
Newport News Shipbuilding	Newport News, Virginia
NKK Corporation	Yokohama, Japan
Odense Steel Shipyard	Odense, Denmark
Onomichi Dockyard Co., Ltd.	Hiroshima, Japan
Oshima Shipbuilding Company, Ltd.	Nagasaki, Japan
Samsung Heavy Industries	Kyungnam, South Korea
Sanoyas Hishino Meisho Corporation	Okayama, Japan
Sasebo Heavy Industries Co., Ltd.	Nagasaki, Japan
Shin Kurushima Dockyard Co., Ltd.	Ochi-gin, Japan
Sumitomo Heavy Industries Co., Ltd.	Kanagawa, Japan
Tsuneishi Shipbuilding Co., Ltd.	Hiroshima, Japan

Classification Societies That Received Questionnaires

Name	*Location*
American Bureau of Shipping	New York, United States
Bureau Veritas	Paris, France
Det Norske Veritas	Hovik, Norway
Gemanischer Lloyd	Hamburg, Germany
Korean Register of Shipping	Taejon, South Korea
Lloyd's Register of Shipping	London, England
Nippon Kaiji Kyokai	Tokyo, Japan
Polish Register of Shipping	Gdansk, Poland
Registro Italiano Navale	Genoa, Italy
Maritime Register of Shipping (formerly Russian Register)	St. Petersburg, Russia

Marine Architects Who Received Questionnaires

Name	*Location*
Beresford House, Town Quay	Southampton, Hants, United Kingdom
George G. Sharp, Inc.	New York, New York
John J. McMullen Associates, Inc.	New York, New York
M. Rosenblatt & Son, Inc.	New York, New York
Three Quays Marine Services	London, United Kingdom

APPENDIX C

Presentations to the Committee

John Hickey
President
American Hull Syndicate

Samuel B. Jones
President
Mallory Jones Lynch Flynn & Associates

John Ferguson
Deputy Chief Surveyor
Lloyd's Register of Shipping

Linwood Poindexter
Vice President
North America Region
ABS America

Yoshiaki Sezaki
Manager
Design Division, Shipbuilding Headquarters
Hitachi Zosen Corporation

John L. Loucas
Vice President
McQuilling Brokerage Partners

Miles Kulukindis
Chairman
INTERTANKO

John L. Newbold
Division Executive

James L. Grubbs
Senior Industry Analyst
Citibank

Nickolai Herlofson
Managing Director
Gard P&I

Eric Shawyer
Chairman and Chief Executive
Gibson's Shipbrokers

Jung Nam Lee
Executive Vice President
Hyundai Heavy Industries Co., Ltd.

APPENDIX D

Information Sources

Source	*Subject*
Clarkson Research, Ltd. London, United Kingdom	current and historical tank ship economics
Fairplay International London, United Kingdom	shipbuilding statistics
Fearnley Research Oslo, Norway	tank ship economics
Institute of Shipping Analysis Göteborg, Sweden	analysis of vessel transit patterns
Lloyd's Maritime Information Services London, United Kingdom	historical vessel data; casualty data
Louisiana Offshore Oil Port (LOOP) New Orleans, Louisiana	offshore port volumes
Maritime Strategies International London, United Kingdom	historical tank ship fleet data; voyage costs
Platou Research A.S. Oslo, Norway	shipbuilding prices
Tanker Advisory Center, Inc. New York, New York	vessel and fleet grading systems
United Tankers Göteborg, Sweden	petroleum product trade

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